EM 1110-2-5026
30 June 1987

US Army Corps
of Engineers

ENGINEERING AND DESIGN

Beneficial Uses of Dredged Material

ENGINEER MANUAL

DEPARTMENT OF THE ARMY EM 1110-2-5026
CEEC-EH-D U. S. Army Corps of Engineers
Washington, D. C. 20314-1000

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BENEFICIAL USES OF DREDGED MATERIAL

1. Purpose. This manual provides guidance for planning, designing, developing, and managing dredged material for beneficial uses, incorporating ecological concepts and engineering designs with biological, economical, and social feasibility.

2. Applicability. This manual applies to all HQUSACE/OCE elements and all field operating activities (FOA) having civil works design responsibilities.

3. General. Beneficial uses of dredged material have been proven on numerous sites in United States waterways. This manual will be helpful to Corps of Engineers scientists and engineers responsible for dredging and dredged material disposal using environmentally, economically, and socially sound techniques and beneficial use management strategies.

FOR THE COMMANDER:

ROBERT C. LEE
Colonel, Corps of Engineers
Chief of Staff

CEEC-EH-D

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CHAPTER 1

INTRODUCTION

1-1. Purpose. This manual provides guidance for planning, designing, developing, and managing dredged material for beneficial uses, incorporating ecological concepts and engineering designs with biological, economical, and social feasibility.

1-2. Applicability. This manual applies to all HQUSACE/OCE elements and all field operating activities having Civil Works design responsibilities.

1-3. Background. Dredged material disposal provides opportunities for a number of environmental, economic, and aesthetic beneficial uses. Innovative beneficial uses appear to be unlimited, and over 1,300 cases of beneficial uses of disposal sites have been documented in North America alone.

a. Ten broad categories of beneficial uses have been identified, based on their functional use of dredged material at disposal sites. They are:

(1) Habitat development (wetland, upland, island, aquatic, including migratory and nesting use by waterbirds, shorebirds, waterfowl, and other groups).

(2) Beach nourishment.

(3) Aquaculture.

(4) Parks and recreation (commercial and noncommercial).

(5) Agriculture, forestry, and horticulture.

(6) Strip mine reclamation and solid waste management.

(7) Shoreline stabilization and erosion control.

(8) Construction and industrial use (including port development, airports, urban, and residential).

(9) Material transfer (fill, dikes, levees, parking lots, roads).

(10) Multiple purpose.

b. Recognition of the ecological value of many areas that have been historically used as dredged material disposal sites has resulted in severe environmental constraints on location and placement of disposal sites, especially those in open water and wetlands. These constraints have increased the values placed on coastal and riparian wetlands and aquatic areas, and have increasingly accented the need for alternate methods of dredged material disposal. As land uses have changed and areas once available for dredged material disposal have become scarce, the concept of beneficial use of dredged material disposal sites, such as land improvement and habitat development, have become more attractive economically and more environmentally acceptable. Dredged material is a manageable, valuable soil resource, with beneficial uses of such importance that plans for ultimate use of disposal sites should be incorporated into project plans and goals at the project’s inception.

c. The known and potential effects of dredging and dredged material disposal on the environment in and around U. S. waterways has led to considerable research efforts and interagency and intraagency coordination. Many waterway projects involving dredging have purposes which require consideration of ecological effects. While maintenance of navigable channels is the prime objective, the development and application of beneficial alternatives for dredged material disposal must receive appropriate consideration.

1-4. Environmental Considerations.

a. Since enactment in 1969 of the National Environmental Policy Act (NEPA) with its requirement for environmental full disclosure (including, in this case, a detailed accounting of disposal alternatives), pressure for greater reliance on confined or on-land disposal of dredged material has increased significantly. At the same time, upland disposal sites are being rapidly depleted due to urbanization, agriculture, and utilization of available capacity in existing sites. Concerns for improvement and/or maintenance of water quality and protection of aquatic nursery, spawning, fish passage and migration, and feeding areas have been factors in removing open-water and peripheral wetlands from the inventory of potential disposal sites (Item 81). It should be noted that, except in cases of contaminated material, the dredging operation does not cause a great deal of concern with regulatory agencies. Although neither open waters nor wetlands can be categorically dismissed from consideration as disposal options, dredgers have generally turned their attention toward uplands, transferring the disposal problem from an aquatic to a land environment except in specific cases such as the lower Mississippi River where 50 square miles of marsh are being lost each year to subsidence and erosion. There, marsh is being purposefully created by disposal in shallow open water. Efforts to control land use have increased and intensified due to advancing urban sprawl, its attendant reduction in natural or open areas, and, even more recently, a heightened awareness of the socioeconomic and environmental impacts associated with uncontrolled development. In recent years, only in the special case of the Great Lakes where in-lake confined disposal facility (CDF) islands have been built, and in certain harbors where CDF’s and islands were permitted, has land been created where an aquatic environment previously existed.

b. In this context, the legal/regulatory framework associated with control of the entire dredging and disposal operation must be considered. Degrading water quality has caused greater emphasis to be placed on assessing hypothetical impacts of disposal operations in open waters and wetlands. These concerns have led to a profusion of legislation at the Federal, state, and local levels designed to control nearly every facet of the dredging and disposal operation.

c. With the realization of the expanding and changing legal framework, keeping abreast of variations in legislative trends and societal attitudes is necessary to ensure comprehensive planning and development of all projects. Federal and state roles and interactions affect implementation of the beneficial use of dredged material. Although the primary impact and concern of legislation is associated with the disposal operation, most laws make no distinction between dredging and disposal. The state regulatory agencies have a major role in the implementation of programs designed to beneficially use dredged material in state-controlled waters or under the jurisdiction of approved state coastal zone management programs. As societal pressures for the wise use of environmental resources grow, changes in institutional arrangements are likely to continue.

d. The Federal Government is a major landholder, but is not a major land controller. As derived from their police powers, state and local governments retain most of the land use control authority. The Federal role is founded upon the Commerce Clause (Article I, Section 8, U.S. Constitution), which limits the Police Power insofar as local, state, and private activities adversely affect interstate commerce. This regulatory power has been defined to include regulation of the use and development of navigable bodies of waters and their beds in the public interest. Such power is referred to as "navigation servitude" and is vested in the Corps of Engineers (CE). This navigational servitude, and Federal grants, technical assistance, and aid programs, causes a predominant role in the regulatory hierarchy. Primarily, the Federal government provides legislative leadership.

e. Although there are more than 30 Federal laws and Presidential Executive Orders (EOs) applicable to beneficial use activities, documentation or public coordination is only required when a beneficial use falls within the specific jurisdiction of a law or EO. The requirement to demonstrate compliance in some cases, such as in EO 11988, is little more than a sentence or two in the NEPA document. In other instances, such as the Clean Water Act of 1977 (CWA), extensive coordination and environmental evaluations may be required. Further, the environmental compliance process for private versus CE dredging and disposal is different. All activities in navigable waters and wetlands require authorization by permit from the CE, while CE activities must demonstrate compliance with the applicable environmental laws. State requirements are independent of the Federal environmental compliance process. However, all state requirements should have Federal statutory reference.

f. Federal institutional constraints are manifested through the Federal environmental protection statutes. Some of the statutes provide categorical protection for certain animal species or prohibit any activity in a particular area, i.e. the Endangered Species Act and cultural resource laws. Other laws require a step-by-step approach to demonstrate compliance before an action may proceed. Careful evaluation of the proposed beneficial use activity against the requirements of environmental protection statutes is essential to ensure that the public does not perceive the action solely as a means of "disposing" of dredged material. Appropriate actions should be undertaken to mitigate for those unacceptable adverse environmental consequences. It is expected that beneficial use projects will result in environmental benefits that can offset adverse consequences of existing projects and future projects as well.

g. Laws in many states can be categorized as state zoning laws, where the state has taken express and direct control over land use. The states traditionally ceded a large portion of land use regulation to local government, but a reversal of that tradition is occurring. Over half the states have general land-use programs. Twenty-four of these programs establish state authority to coordinate major local land-use decisions, nine take the more traditional approach of mandatory local planning, and five are comprehensive state, programs involving land-use permits to deal directly with land development. Thirty eligible states participate in the CZMA, five had special laws to protect their shorelines, 22 had wetlands protection laws, 26 regulated development in the floodplain, and 13 had legislation to protect defined critical areas. Item 14 surveyed a 16-state sample of laws impacting on the planning and implementation of dredged material containment areas. These state laws generally fall into two major categories: those directed primarily toward environmental protection and those directed toward land-use control. The two categories are not mutually exclusive, and much crossover exists. The environmental laws are generally more recent and broader in scope in their emphasis on the preservation of land, water, and other natural resources. The land-use control laws reflect a trend away from local control and toward state regulation.

h. Land use plans developed by local, regional, or state management agencies may necessitate coordination for beneficial use activities such as borrow pit or land fill reclamation. Development of the beneficial use activity in conjunction with the appropriate planning agency normally satisfies the applicable land use requirements. State regulation of beneficial use activities is based in the Federal statutes. Activities occurring in state waters, to include the territorial sea, or in approved coastal zones may be regulated by the state under the provisions of the CWA or Coastal Zone Management Act (CZMA). Depending upon the nature and location of the proposed activity, certifications and/or consistency determinations may be required.

i. Through the provisions of the CWA and CZMA, states have the authority to regulate most beneficial use activities. State procedural requirements are independent of Federal compliance. Although the CE and most states have established joint evaluation procedures, about 30 days should be added to the compliance process to accommodate state review. States may, as a prerequisite to the required certifications, add conditions or controls to the proposed beneficial use activity. Such conditions or controls should be directly related to state water quality standards or coastal zone program.

State fish and game agencies under the authority of the Fish and Wildlife Coordination Act of 1958 (FWCA) may recommend conditions to protect environmental resources of concern, i.e., oyster reefs, shrimp, wetlands, or other sensitive resources. Further, state-listed endangered species not on the Federal list will be of concern to state fish and game agencies. Coordination with state agencies is accomplished through the public notification process.

1-5. References. References which can provide guidance leading to this manual are:

a. 16 U.S.C. 661, Public Law 85-624, Fish and Wildlife Coordination Act of 1958.

b. 42 U.S.C. 4321 et seq., Public Law 91-190, National Environmental Policy Act.

c. 33 U.S.C. 1251 et seq., Public Law 92-500, Clean Water Act of 1977.

d. 33 U.S.C. 1401 et seq., Public Law 92-532, Marine Protection, Research, and Sanctuaries Act of 1972.

e. 16 U.S.C. 1451, Public Law 92-583, Coastal Zone Management Act.

f. 33 U.S.C. 426, Public Law 94-587, Water Resources Development Act of 1976.

g. Executive Order 11988, May 1977, Floodplain Management.

h. ER 1105-2-35, Public Involvement and Coordination.

i. ER 1105-2-40, Economic Considerations (CH 1-3).

j. ER 1105-2-50, Environmental Resources (CH 1-2).

k. ER 1110-2-400, Design of Recreation Sites, and Areas and Facilities (CH 1).

l. ER 1165-2-27, Establishment of Wetlands Areas in Connection with Dredging.

m. EM 1110-2-1902, Stability of Earth and Rock Fill Dams.

n. EM 1110-2-2300, Earth and Rock-fill Dams; General Design and Construction Considerations.

o. EM 1110-2-5025, Dredging and Dredged Material Disposal.

p. EP 1165-2-1, Digest of Water Resources Policies and Authorities.

1-6. Bibliography. Bibliographic items are indicated throughout the manual by numbers (item 1, 2, etc.) that correspond to similarly numbered items in Appendix A. They are available on loan from the Technical Information Center, U. S. Army Engineer Waterways Experiment Station, P. 0. Box 631, Vicksburg, MS 39180-0631.

1-7. Plant Material Recommendations. Appendix B contains detailed information for propagation and planting of 359 native and cultivated upland plant species and 105 wetland plant species that can be used for beneficial use development on dredged material and other disturbed sites.

1-8. Beneficial Use Case Studies. Over 1,300 examples of beneficial uses of dredged material in the United States and Canada are given by region in Appendix C. These indicate the extent to which dredged material is now being used as a resource and as a valuable commodity.

1-9. Plant and Animal Species. Common and scientific names of all plant and animal species are listed in Appendix D, by alphabetical order according to common name.

1-10. Definitions. A glossary of key environmental, dredging, and engineering terms follows the appendixes.

CHAPTER 2

DREDGED MATERIAL AS A RESOURCE

2-1. General.

a. The Dredged Material Research Program (1973-1978), the Dredging Operations Technical Support Program (1978-present), and the Environmental Effects of Dredging Program (1982-present) have determined the environmental impacts of dredged material disposal, alternatives to increase the beneficial use of dredged material, and means to reduce the adverse effects of both land and water dredged material disposal. Increased interest in dredged material as a manageable, beneficial resource as an alternative to conventional disposal practices is due to the fact that, while the amount of material dredged each year continues to rise, increasing urbanization around waterways and ports has made it difficult to locate new sites for containment areas. New environmental regulations have further restricted both land and water disposal options. Costs of dredged material disposal have increased rapidly as disposal sites are located at greater distances from the dredging site and environmental controls are added. By considering dredged material as a resource, a dual objective can be achieved. The dredged material from needed navigation projects can be disposed of with minimal environmental damage, and benefits can accrue from its use.

b. Physical, engineering, and chemical characteristics of dredged material proposed for beneficial use and land enhancement projects must be identified. This includes examination of contaminants. Such information is essential for evaluating the suitability of the material for numerous alternative uses. These characteristics must be determined during the initial stages of planning since proposed uses may prove infeasible due to unsuitable material. Chapter 2 presents discussions of the physical, engineering, and chemical characteristics of dredged material, contaminant and water quality considerations, and some of the limitations which may be encountered with dredged material substrates that may preclude alternatives. Most dredged material is below contaminant levels that would preclude a beneficial use.

2-2. Physical and Engineering Characteristics.

a. Physical Characteristics. A number of standard soil properties are used to determine the physical and engineering characteristics of dredged material (item 3). Soil tests include grain-size, plasticity, and organic content determinations. Engineering tests include compaction, consolidation, and shear strength. Item 4 indicates that dredged material is made up of various types of soil that can be classified under the Unified Soil Classification System (USCS) (item 60).

(1) Grain size. Grain size is the principal physical characteristic to be determined when considering dredged material for beneficial uses, and grain size is also the basis for most soil classification systems. Land enhancement

guidelines presented in this EM for the beneficial uses of dredged material include engineering, environmental, and agricultural projects. For this reason, both the USCS (item 60) and U.S. Department of Agriculture (USDA) (items 6 and 38) classifications are used. The USCS method emphasizes characteristics of a construction material, whereas the USDA method emphasizes soil agricultural properties. The USCS method is the method most often used for classifying dredged material, but for certain beneficial uses it may be necessary to use the USDA method.

(2) Bulk density. Bulk density is a weight measurement by which the entire soil volume is taken into consideration. The bulk density of dredged material is usually low for fine-grained material, but a highly productive agricultural loam soil can range from 70 to 86 pounds per cubic foot (item 38). These low bulk densities in fine-grained dredged material can be attributed to the sedimentation process and the amorphous nature of the clay. Bulk density data are needed for converting water percentage by weight to water content by volume for estimating the weight of a large volume of material. Examples are the weight of dredged material in a disposal site or estimating the volume of dredged material in a dump truck, barge, or railroad car.

(3) Plasticity. For USCS classification, the Atterburg liquid limit (LL) and plastic limit (PL) must be determined to evaluate the plasticity of fine-grained sediment samples. The LL is that water content above which the material is said to be in a semiliquid state and below which the material is in a plastic state. Water content (item 68) which defines the lower limit of the plastic state and the upper limit of the semisolid state is termed the PL. The plasticity index (PI), defined as the numerical difference between the LL and the PL, is used to express the plasticity of the sediment. Plasticity analyses should be performed on the separated fine-grained fraction of dredged material samples.

(4) Specific gravity. Values for the specific gravity of solids for fine-grained sediments and dredged material are required for determining void ratios, conducting hydrometer analyses, and consolidation testing.

(5) Water retention and permeability. Water retention characteristics of soil describe the energy relation of soil to water, can be used to determine the availability of water to plants, describe the moisture-storing capacity of a soil (dredged material), and are strongly influenced by the arrangement of the solid components and the quantity of fine particles and organic matter (Table 2-1). The potential available water capacity of a field soil is defined as the amount of water a crop can remove from the soil before its yield is seriously affected by drought (Table 2-2). The permeability and sorptive properties of a material express the ease with which water will move or pass through (Figure 2-1). Permeability is determined by a number of factors; however, size of soil pores and magnitude of soil water retention are most important.

Table 2-1

Available Water Capacity of Soils of Different Grain Size Range*

Grain Size Range	Available Water Capacity at Saturation, Inch of Water per Inch of Soil Depth
Sand	0.015
Loamy sand	0.074
Sandy loam	0.121
Fine sandy loam	0.171
Very fine sandy loam	0.257
Loam	0.191
Silt loam	0.234
Silt	0.256
Sandy clay loam	0.209
Silty clay loam	0.204
Sandy clay	0.185
Silty clay	0.180
Clay	0.156

* Source: item 25.

Table 2-2

Available Water Capacity Suitable for Agricultural Crops*

Available Water Capacity, Inch Water/Inch of Soil	Total Available Water Capacity, Inches per Yard of Soil Depth	Recommended Plants
0.05	1.8	Not suitable for most agricultural crops unless irrigated
>0.05-0.075	>1.8-2.7	Best suited for grasses
>0.075	>2.7	Suitable for most agricultural crops

Source: item 25.

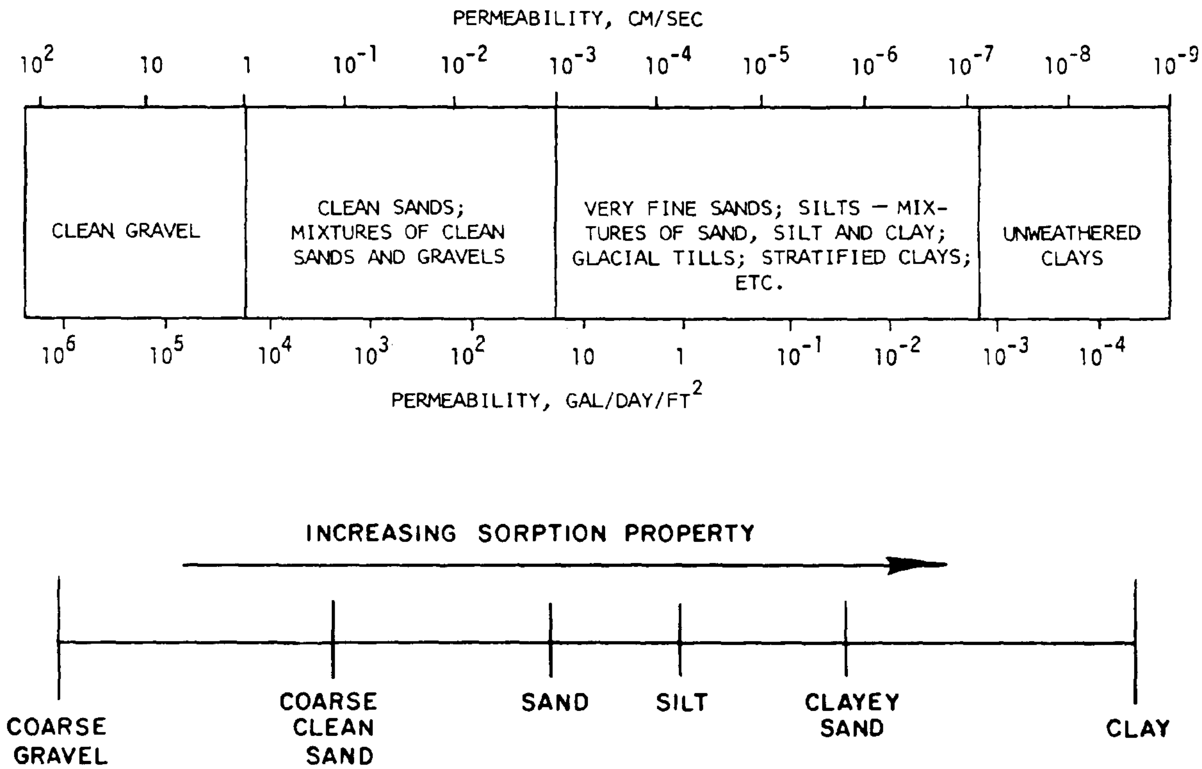


Figure 2-1. Range in permeability and sorptive properties of different soil classes (item 68)

(6) Volatile solids. Volatile solids are important in determining contaminant retention within a soil or dredged material, and for the material's capacity for plant growth and beneficial use.

b. Physical properties of dredged material. When hydraulically placed into a disposal area, dredged slurry can have a dry solids content ranging from near 0 to approximately 20 percent by weight (item 33). Generally, this value is about 13 percent. As the slurry flows across the disposal area, the solid particles settle from suspension: coarse particles near the inlet (dredge pipe), fine particles farther into the area, and finest materials in the immediate vicinity of the outlet weir. As a disposal operation progresses, coarse-grained dredged material may accumulate in a mound and displace the soft fine-grained dredged material.

(1) During and after the disposal operation, surface water is drained from the disposal area. A surface crust begins to form on fine-grained dredged material as it desiccates. Over time, surface and base drainage cause some lowering of the ground-water table, the surface crust continues to increase in thickness, secondary compression effects develop, and

consolidation occurs as the effective material weight above the ground-water level is increased from a submerged weight to a saturated weight. The dredged material below the surface crust remains very soft and weak.

(2) The water content of fine-grained dredged material in disposal areas is generally less than 1.5 times the LL of the material, and it is possible that in freshwater areas the water content is about equal to the LL. The LL of dredged material is generally less than 200, with most values being between 50 and 100.

c. Engineering Properties of Dredged Material.

(1) Engineering properties are critical to determining the types of beneficial uses possible. Soft, fine-grained dredged material has little load-bearing capacity, and can generally be used only on sites not involving heavy structures or intensive activities (urban, recreational, other). EM 1110-2-5025 contains more detailed information concerning physical and engineering properties.

(2) The surface crust associated with fine-grained material usually has a very low water content (often near the shrinkage limit) that increases slightly with increasing depth of the crust. The crust is usually overconsolidated due to the increase in effective stress caused by high negative pore pressure resulting from evaporation. Below the surface crust, however, the fine-grained material is extremely soft, with water content usually showing little change from the time of deposition. Density and shear strength increase very slightly, if at all, with increasing depth. Data show that engineering properties are generally better near the inlet than the outlet because the coarse-grained material settles near the dredge discharge. The engineering properties of the fine-grained material in the containment area near the outlet are poorer and improve very slowly with time. In general, dredged material is soil with a high water content, that upon dewatering exhibits soil properties with a high beneficial use potential.

2-3. Chemical Characteristics.

a. General. Dredged material characteristics reflect the population, industry, and land uses of an area (item 81). The chemical constituents of dredged material help determine the suitability of that material for a particular land use (item 11). Chemical analysis of the dredged material must be made to indicate potential detrimental effects on the environment in the disposal area. Four potential problem areas exist depending on the presence of available chemical constituents in the dredged material: plant toxicity, animal toxicity, surface water contamination and ground-water contamination (items 44 and 53). Plant uptake of chemicals may also present problems if growth or reproduction potential of the plant is altered or if harmful chemicals are passed via the food web into higher organisms.

b. Cation Exchange Capacity. The capacity of soil particulates to adsorb nutrients which become available for plant growth is called the cation exchange capacity (CEC). Adsorbed or sorbed nutrients are readily available to higher plants and easily find their way into the soil solution. The grain size and organic content of sediments determine to a large extent the capacity of that material to sorb and desorb cations, anions, oil and grease, and pesticides. Silts and clays with relatively high organic contents can sorb and fix large amounts of plant nutrients as well as many other constituents (Figure 2-1). The CEC of dredged material governs the sorption of nitrogen and potassium, heavy metals, and some pesticides. The nutrient content of dredged material varies widely, as does that of different soils. Generally, fine-grained dredged material contains considerably more nutrients than coarse-grained material and is also more likely to contain one or more contaminants.

c. Nitrogen. The total nitrogen content of dredged material varies widely with geographic location. The most predominant form of nitrogen in inorganic sediments is ammonium nitrogen. In organically enriched sediments, organic nitrogen predominates, even though ammonium concentrations can be very high.

d. Sulfur. Item 44 indicates that sediments in a South Carolina tidal marsh developed high acidity when drained and dried. These sediments contained up to 5.5 percent total sulfur. When drained, sulfides were oxidized to sulfate with a resultant decrease in sediment pH from 6.4 to as low as 2.0. This effect may be a serious problem in dredged material containing high levels (usually greater than 0.1 percent) of nonvolatile sulfide, predominantly iron and manganese sulfide. This is especially true if the dredged material is not limed or its acidity is not otherwise counteracted by application to an alkaline upland soil.

e. Heavy Metals.

(1) A wide range of heavy metal concentrations has been reported in a number of sediments from rivers, harbors, and bays throughout the United States and Canada, primarily in intensely urban and highly industrialized regions. Some of the major sources of heavy metals include industrial and sewage discharges, urban and highway runoff waters, and snow removal. Wastes from metal plating industries that have found their way into some sediments contain significant amounts of copper, chromium, zinc, nickel, and cadmium. Chemical partitioning studies of sediments have shown that these metals occupy the least stable of the sediment fractions and that the sediment chemistry dominates the mobility and availability of the contaminant as well as the indigenous metals.

(2) An important heavy metal consideration is the solubility of specific constituents whose concentrations are high, since soluble forms are readily available to the biological food web. The potential of a heavy metal to become a contaminant depends greatly on its form and availability rather

than on its total concentration within a dredged sediment (item 44). Heavy metals may be fixed in a slightly soluble form in dredged material containing excessive sulfide. The land application of dry oxidized dredged material may increase the solubility of heavy metal sulfides. However, under oxidizing conditions, the levels of pH and heavy metal hydroxyl and oxide formation become the important factors, and sulfur no longer governs the solubility and availability of heavy metals (item 25).

(3) Until Federal standards are set for sediments, guidelines for dredged material disposal must be taken from other research areas such as sludge disposal. The USDA has been investigating the application of sewage sludge to agricultural lands. Recommended maximum limits on the metal content of sludge are shown in Table 2-3.

Table 2-3

Recommended Maximum Limits for

Metal Content in Digested Sewage Sludges*

Element	Domestic Sludge Concentration, ppm
Zinc	2,000
Copper	1,000
Nickel	200
Cadmium	15 or 1.0% of zinc
Boron	100
Lead	1,000
Mercury	10
Chromium	1,000

Source: item 9.

* Typical sludge from communities without excessive industrial waste inputs or with adequate abatement.

In most cases, the heavy metal contents of dredged material fall below the maximum allowable limits recommended in domestic sewage applied to land. If higher concentrations of chemical constituents are found in dredged material, it should not be used in a land improvement project without prior treatment to remove or reduce contaminants.

2-4. Water Quality Considerations.

a. Ecological impacts of the discharge of dredged or fill material can be divided into two main categories: physical effects and chemical-biological interactive effects. Physical effects are often straightforward, and evaluation may often be made without laboratory tests by examining both the character of the dredged or fill material proposed for discharge and the sediments of the disposal area. On the other hand, chemical-biological interactive effects resulting from the discharge of dredged or fill material are usually difficult to predict.

b. Natural processes in aquatic ecosystems tend to concentrate heavy metals, chlorinated hydrocarbons, pesticides, nutrients, and oil and grease compounds in bottom sediments. These contaminants are not very soluble in water under the conditions that normally occur in oxygenated uncontaminated surface waters. Therefore, introducing high concentrations of these contaminants into aquatic ecosystems will generally result in an equilibrium condition where most of the contaminant will be sorbed (adsorbed and absorbed) by suspended particulate material and then deposited on the bottom when the suspended material settles. The time necessary to achieve the equilibrium condition depends upon the physicochemical conditions in the aquatic system and the quantity and duration of the contaminant introduction. There has been concern that dredging and open-water disposal operations may release these trapped contaminants again, and thus have the potential to damage wetland, upland, and aquatic environments. WES reports (items 7 and 23) and other literature indicate that dredging operations have the potential to temporarily mobilize or release some contaminants from the sediments. During disposal operations, the anaerobic sediments are mixed with aerated surface water, and a complex chemical interaction occurs. Heavy metals such as cadmium, copper, chromium, lead, and zinc, which had been stabilized in oxygen-free sediments, form precipitates and coagulate in the presence of oxygen. Phosphorus and nitrogen can be temporarily released into the water column, while pesticides and oils and grease are usually not very water soluble. However, all of these contaminants have the potential to affect a proposed beneficial use project.

c. The Environmental Protection Agency (EPA), in conjunction with the CE, has published a comprehensive procedure manual (items 23 and 66) that contains summaries and descriptions of tests, definitions, sample collection and preservation procedures, analytical procedures, calculations, and references required for detailed water quality evaluations. The purpose of this is to provide state-of-the-art guidance on the subjects of sampling, preservation, and analysis of water and dredged and fill material. The interim guidance for implementing Section 404(b) of the Clean Water Act was published in 1976 (item 18). It has also been published jointly by the EPA and the CE pursuant to the Marine Protection, Research, and Sanctuaries Act of 1972, which addresses the primary intent of Section 103 of regulating and limiting adverse ecological effects of ocean dumping.

2-5. Contaminated Dredged Material. Over 90 percent of the total volume of dredged material is considered acceptable for disposal at a wide range of disposal alternatives. However, the presence of contamination in some locations has generated concern that dredged material disposal may adversely affect water quality and aquatic or terrestrial organisms. Since many of the waterways are located in industrial and urban areas, some sediments may be highly contaminated with wastes from these sources. In addition, sediments may be contaminated with chemicals from agricultural practices. The EPA guidance in Section 230.60 (Federal Register, Vol. 45, No. 249) should be used to determine whether there is sufficient cause for concern to warrant testing for contaminants and to identify the contaminants of concern.

2-6. Biological Limitations. Although dredged material has been generally found to be a soil resource of great value and use, it has some limitations as a beneficial product.

a. Texture and Physical Characteristics. Dredged material is composed predominantly of mineral particles ranging in size from coarse sand to fine/ clay and can have an extremely mixed mineralogy (item 44). Dredged material deposits within one disposal site can vary from well-ordered sand to organic clay. In addition to soil, dredged material may contain other solids such as rock, wood, pieces of metal, glass, and other debris. Contamination of these sediments in the form of organic material, elevated concentration of heavy metals, a vast array of chlorinated hydrocarbons, oil and grease, and other organics reflects the influences of population and industry in the area. The actual physical texture of the material on a site may limit its use; i.e., pure sand dredged material would not be suitable for agricultural land applications. However, as fill material and for some dike construction, it may be excellent. Predominantly uncontaminated silt would not be well suited for waterbird island construction, but would make an excellent soil addition for agriculture and forestry, and for some habitat development sites.

b. Contamination.

(1) In certain areas of the United States, such as near certain industries or extensive agriculture, contamination is an important factor to be considered. If the dredged material contains contaminants, it may have to be placed in a confined disposal site, which will probably limit its beneficial use. Planning for beneficial use of contaminated dredged material should consider the following factors:

(a) Amounts and type of contaminants in the material, possibly to include heavy metals, fertilizers, sewer wastes, pesticides, or petroleum products.

(b) Maximum acceptable levels for pollutants in water, soils, plants, and animals as set by the EPA.

(c) Kinds of plants and animals that will be on the site, their abilities to regulate uptake of these pollutants, and their tolerance levels before life efficiency is reduced, reproduction ceases, or death occurs.

(d) Chances of biomagnification via the food chain from plants, invertebrates, and microbes to animals on the site or to humans.

(e) Impact of contaminants on the site and surrounding areas.

(2) Item 46 and other studies have shown that plants grown in dredged material wetlands absorb heavy metals in varying degrees depending upon the plant species. These contaminants in most cases are not generally translocated into the top shoots but are retained primarily in the root systems. Most potential danger is limited to users of the root systems, such as waterfowl that feed on plant tubers. However, research on plants grown in dredged material upland areas indicates a tendency to accumulate heavy metals in all plant parts, including stems and seeds.

(3) Many pesticides, chemical by-products, and petroleum products in dredged material have unknown biomagnification abilities. It is known that some pesticides have affected reproductive abilities of birds by causing eggshell thinning and behavior modification. Petroleum products can smother small organisms (potential food items). Fertilizers and sewer wastes in dredged material alter the habitats where they accumulate by changing plant growth habits and species composition and by reducing dissolved oxygen levels in water. This affects the food supply of fish-eating animals. Highly acidic dredged material can severely limit beneficial use options unless corrected with lime. The contaminant problem can be minimized on most beneficial use sites through these management procedures:

(a) Stabilizing the areas with plant species that do not transport contaminants into their top shoots.

(b) Avoiding management for wildlife grazing, fish nursery use, or intense human use to reduce danger of a biomagnification problem.

(c) Managing for animals that will not feed on the site, such as fish-eating birds that use the site for nesting and roosting purposes only. A good example of this is the Toledo Harbor, Ohio, disposal site in Lake Erie that is being filled over a 20- to 30-year period with contaminated dredged material. Common terns, ring-billed gulls, and herring gulls are nesting inside the dikes but do not feed there since they are all fish-eating species.

(4) Contaminated sites can be capped with about 2 feet of clean soil or dredged material. This will allow use of the site for a number of beneficial uses involving shallow-rooted plants, i.e., nesting meadows, recreational sites, etc.

c. Site Habitat Changes. Beneficial uses can frequently mean the replacement of one desirable habitat with another. This will likely be a source of some opposition. There are few reliable methods for comparing the various losses and gains associated with this habitat conversion; consequently, the determination of relative impact may best be made on the basis of relative scarcity or abundance of the new habitat, environmental regulations, or of professional opinions. An example would be changing aquatic or marine habitat to an emergent wetland or an upland site.

d. Impacts on Surrounding Land and Animals. When dredged material is placed on a site for a beneficial use, there may be a number of associated impacts. Examples are increased runoff of nutrient-charged or contaminant-charged effluent, increased human or other animal use, interference on surrounding land such as from increased bird activity at disposal sites near airport runways, increased recreational use in disposal sites subject to heavy industrial and shipping use, and changes in hydrology from additions of water-charged dredged material to new or existing sites.

CHAPTER 3

LOGISTICAL CONSIDERATIONS

3-1. General. With the huge quantities of dredged material created during dredging operations, site utilization, economic transport handling, and storage plans become critical to the overall life and use of a project. This section will discuss procedures for dewatering, transporting, handling and storage, and cost analyses of these activities in determining beneficial use of dredged material. It should be remembered that dewatering is not applicable for some types of beneficial uses such as wetland and aquatic habitat development and aquaculture. However, dewatering is critical to nesting islands, upland habitat development, most kinds of recreational use, agriculture, forestry, horticulture, and other types of beneficial uses.

3-2. Dewatering. Dredged material is usually placed hydraulically into confined disposal areas in a slurry state. Although a significant amount of water is removed from it through the overflow weirs of the disposal area, the confined fine-grained dredged material usually consolidates to a semifluid consistency that still contains large amounts of water. The volume occupied by the liquid portion of the dredged material greatly reduces available future disposal volume. The extremely high water content also may make the dredged material unsuitable or undesirable for commercial or beneficial use. Two dewatering methods, fully described and discussed in items 24, 28, 29, 31, 57, and 84, are generally used. The first method is allowing evaporative forces to dry fine-grained dredged material into a crust while gradually lowering the internal water table. This has been the least expensive and most widely applicable dewatering method identified through dredging research. Good surface drainage, which rapidly removes precipitation and prevents ponding of surface water, accelerates evaporative drying. Shrinkage forces developed during drying return the material to a more stable form, and lowering of the internal water table results in further consolidation. The second method of promoting good surface drainage is by constructing drainage trenches in the disposal area using heavy equipment. Use of a Riverine Utility Craft to make trenches proved successful on disposal sites with fine-grained material. A site must be dewatered sufficiently to accept heavy equipment, which limits the second method in its application as long as 2 years after a disposal site has been filled, depending upon the soil characteristics of the dredged material. A less frequently used method, rarely applied to disposal sites, includes installation of underground drainage tiles or sand layers prior to filling the site.

3-3. Transport, Handling, and Storage. Fundamental features of transport systems and general guidance for analysis of technical and economic feasibility are provided in item 74. They are presented to acquaint planners with the magnitude and scope of the transport system and provide some cost-effective analysis information for five transport modes: hydraulic pipeline, rail haul, barge movement, truck haul, and belt conveyor movement. Hydraulic pipeline and truck haul have been the primary transportation methods used for most existing beneficial use sites. Since the transport of dredged material can be a major cost item in determining the economic feasibility of a project, the transport system should be evaluated early in the site selection stage, of the planning process. Legal, political, sociological, environmental, physical, technical, and economic aspects should be examined in relation to availability of transport routes, A sequence of five steps must be followed when selecting a transport route:

Step	Information Source
1. Identify available routes	Maps, ground reconnaissance
2. Classify nature (wet/dry) of dredged material	Beneficial use needs and sources of dredged material
3. Determine annual volume of dredged material and duration of project	Dredged material sources
4. Estimate cost of available transport modes	Item 74
5. Identify and evaluate technical, environmental, legal, and institutional requirements	Item 74 Specific sources: local, state, and Federal agency regulations

a. Elements of Transport Systems. Transport systems involve three major operations: loading, transporting, and unloading. The loading and unloading activities are situation dependent and are the major cost items for short distance transport. The hydraulic pipeline is the only mode which requires a unique rehandling activity; all other transport modes may interchange loading and unloading operations to suit the specific site needs. Loading, unloading, and transporting operations can be separated into detailed components (i.e., backhoes, service roads, rail spurs, cranes, conveyors, etc.) and each component examined for capacity, operational schedule and cycle, and costs of equipment and operation and maintenance.

b. Transport Modes.

(1) Hydraulic pipeline. The hydraulic pipeline is the only transport system recommended for movement of dredged material in slurry form. Assuming government construction of the disposal site, contractor operations of the dredging work, and no easement costs, this system can be economically competitive for distances up to several miles. The conditioning step requires a rehandling dredge and fluidizing system. Control of density and flow to minimize operational problems is an essential conditioning process unique to the hydraulic pipeline mode. Suggested criteria to be used in selecting a rehandling (or secondary) dredge for operation within a containment area include: unit cost of dredging; ease of transportation; minimum downtime; small size to allow maneuverability in a small basin; capability to dredge in

shallow water to minimize dike height; and maximum cutter width to reduce the number of passes. Numerous dredges fitting these criteria are on the market. Some have additional features, such as cutterheads capable of following natural contours of the basin bottom without damage to natural or man-made seals, wheel attachments for the cutterhead to allow dredging operations in plastic or rubber-lined basins, and capability of dredging forward and backward. The fluidizing system is needed to supply water from the closest source to maintain flotation of the dredge. Unloading facilities are unnecessary since the dredged material slurry is usually pumped out of the pipeline into a containment area. A schematic of rehandling operations for hydraulic pipeline transport is presented in Figure 3-1. The pipeline to the land improvement site would include a pneumatic or centrifugal hydraulic pump booster system and would be automated to the maximum extent possible.. The following items should be taken into consideration in any planning for pipeline transport:

(a) Slurry movement of saline dredged material to a freshwater environment is not recommended.

(b) Dewatering requirements before a beneficial use application may be a cost burden and may require treatment of decanted water.

(c) Building codes, easement acquisition, utility relocation, climatological factors, and urban area disruption from construction may be obstacles.

(d) Confining dikes must be provided and could be a significant cost item.

(e) Right-of-way acquisition.

(f) Federal, state, and local regulations and requirements.

Real estate and right-of-wayÆ easements are very site-specific items of political as well as economic concern. These items can impact greatly on the cost of hydraulic pipeline system and therefore should be given due consideration in any cost-benefit analysis and in the final cost evaluation. Cost guidelines do not take into account expenses due to the uniqueness of each situation.

(2) Rail haul. Rail haul using the unit train concept is technically feasible and economically competitive with other transport modes for hauling dredged material distances of 50 to 300 miles. A unit train is one reserved to carry one commodity (dredged material) from specific points on a tightly regulated schedule. Facilities are required for rapid loading and unloading to make the unit train concept work and to enable benefits from reduced rates on large volumes of bulk movement. Bottom dump cars or rotary car dumpers are needed to meet the rapid loading and unloading requirement. Economic feasibility demands the utilization of existing railroad tracks; however, the building of short intermediate spurs may be required to reach disposal areas.

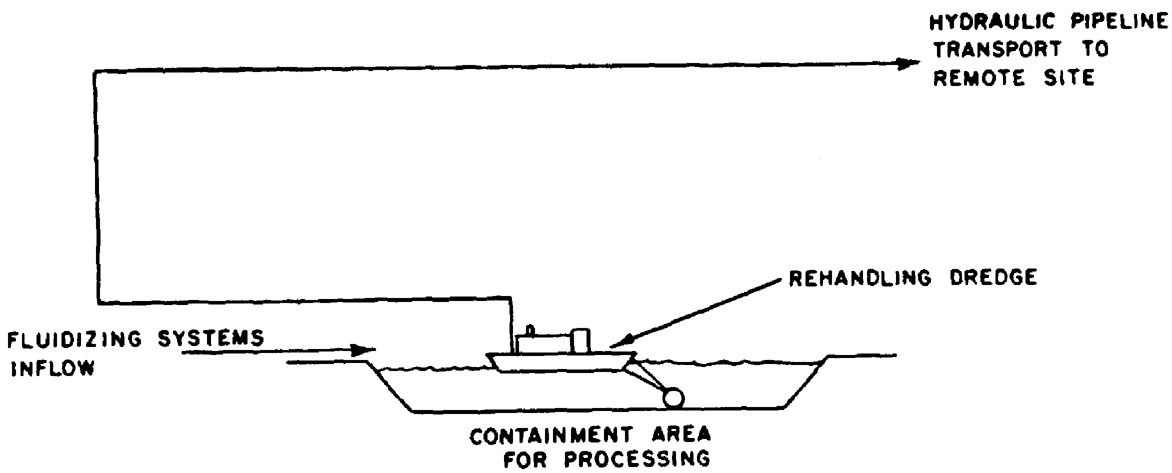


Figure 3-1. Schematic of rehandling system for hydraulic pipeline

Figure 3-2. Tugboat and barge transporting dredged material

The following items should be taken into consideration in any planning for rail haul transport to a beneficial use site:

(a) Dredged material must be dry enough to free-fall from cars.

(b) Scheduling and length of unit trains are often strictly regulated.

(c) State regulations may require open hopper cars to be covered.

(d) Dual use of hopper cars may require washing of cars between use and treatment of wash water to prevent contaminant transfer.

(3) Barge movement. Depending upon the volume of material to be moved, barge movement can be an economically competitive transport mode for the movement of dredged material up to 300 miles. Barge haul was used in the Sacramento District to remove 7 million cubic yards (yd^3) of dredged material from Grand Isle (Figure 3-2). To ensure reasonable costs, a barge unit should consist of familiar and available equipment. In addition, loading and unloading mooring docks capable of accommodating the two cargo scows simultaneously must exist with roadways between the docks and disposal areas to make barge transport practical. The following items should also be taken into consideration:

(a) Thorough information must be obtained about the waterway: navigation depth, allowable speed, lock size, traffic density and patterns, etc.

(b) Often, regulations exist concerning cleanup responsibilities with associated fines for spills in inland waters.

(c) Climatic conditions may affect operational schedules.

(d) A user charge for waterways may become a reality in the future.

(4) Truck haul. Truck haul of dredged material can be economically competitive for distances up to 50 miles. At greater distances, transport by truck is labor- and fuel-intensive and not economically justifiable. The simplicity of loading and unloading requirements and the relative abundance of available roadways make truck hauling technically the most attractive transport mode, and it has wide District application (Figure 3-3). Costs analyses are based on utilizing 25-ton dump trucks with 8.5-yd^3 capacities and assume that routes exist which are adequately upgraded and maintained. Economic feasibility of truck hauling is based on rates established by negotiation with trucking companies and include all associated driver and fuel costs. The following items should also be taken into consideration:

(a) State highway and safety regulations cover a variety of elements (gross weights of trucks, weight per axle, etc.).

(b) Emission and noise standards.

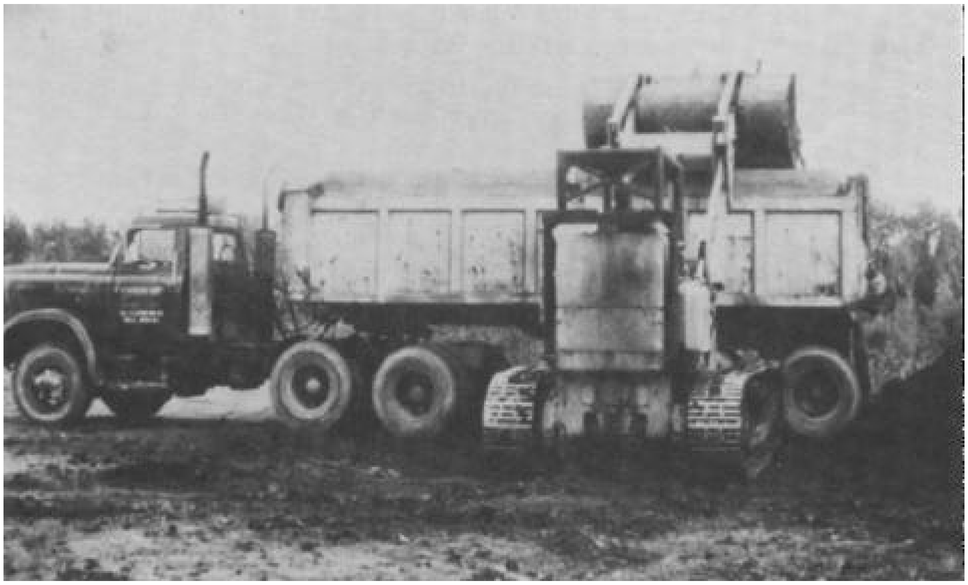


Figure 3-3. Truck haul utilized by the Chicago District

Figure 3-4. A 36-inch belt conveyer loading operation

(c) Local ordinances designating truck routes.

(d) Traffic control of truck operations during winter months in northern climates.

(e) Weight limits on bridges and roadways.

(5) Belt conveyor movement. Belt conveyor systems are employed on a limited basis to transport relatively dry dredged material for short distances. They are technically feasible and cost competitive. Belt specifications vary in width (30 to 70 inches), flight length (900 to 2,600 feet), and speed (7 to 90 miles per hour). Systems can be designed to suit project needs excluding certain terrain difficulties. Because of system flexibility, belt conveyors fit neatly into many loading and unloading operations. The California Highway Department, under an agreement with the Sacramento District, uses dozers and conveyors to load dredged material onto barges (Figure 3-4). The following items should be taken into consideration in any planning for belt conveyor transport:

(a) Building codes, easement acquisition, utility relocation, climatological factors, and urban area disruption for construction may be obstacles.

(b) Material pileup due to system failure.

(c) Malfunctions of sequential belt systems resulting in entire system stoppage.

c. Loading and Unloading Elements. Loading and unloading elements may incur high costs which can restrict project viability. Item 74 presents several examples of loading and unloading options and schematics of scenarios associated with various dry material transport modes; two examples are shown in Figures 3-5 and 3-6. Two other examples include a pair of backhoe excavators and a series of conveyor belts providing rapid loading of unit trains, and a barge haul scheme using backhoes for excavation and loading directly into dump trucks which make the intermediate haul to the scows. In this EM, cost comparisons are based on the loading and unloading component scenarios presented in Item 74. The truck haul loading element components are similar to the rail loading components which include excavation backhoes and a series of belt conveyors. The unloading system is simple back-dumping at the beneficial use site. Placement methods are important, and are discussed in Chapter 5 and other chapters where critical elevations are needed for beneficial use applications.

3-4. Cost Analysis for Dewatering and Transport.

a. Dewatering Costs. Costs associated with dewatering of dredged containment areas are directly related to the degree of trenching effort required and the type of heavy equipment necessary to accomplish dewatering. Thus, the program costs for progressive trenching are highly site-specific depending

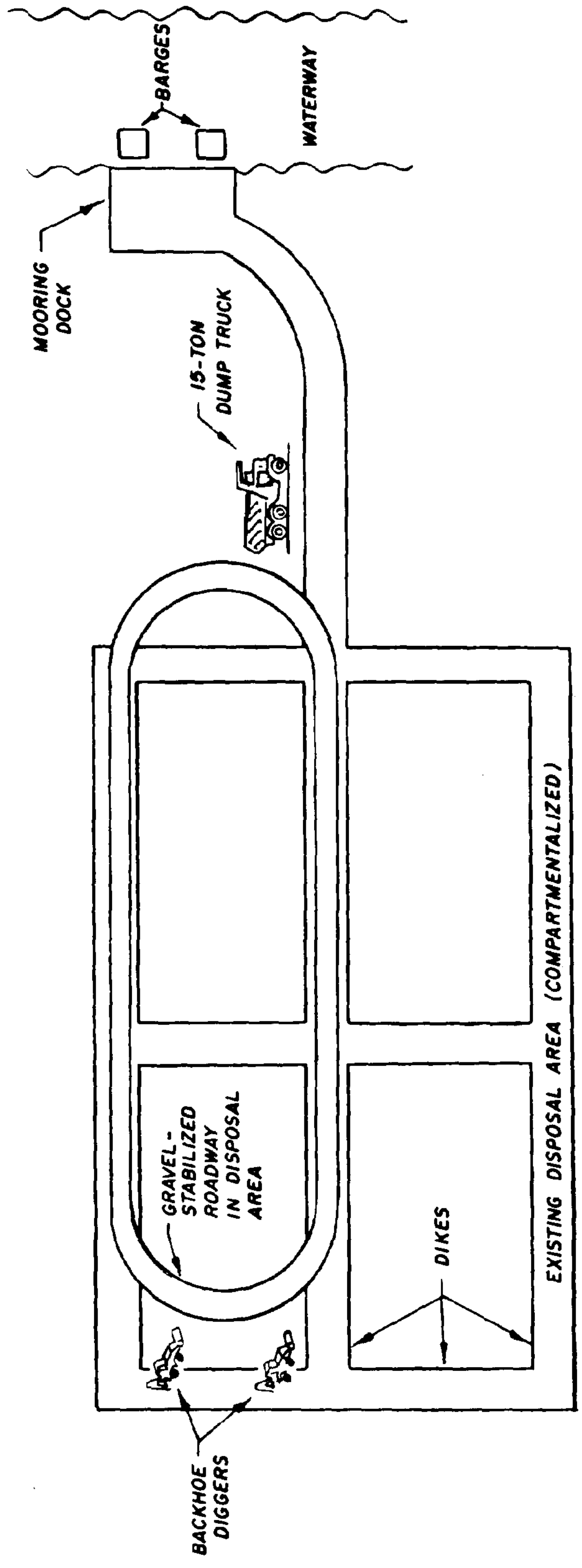


Figure 3-5. Barge loading operation

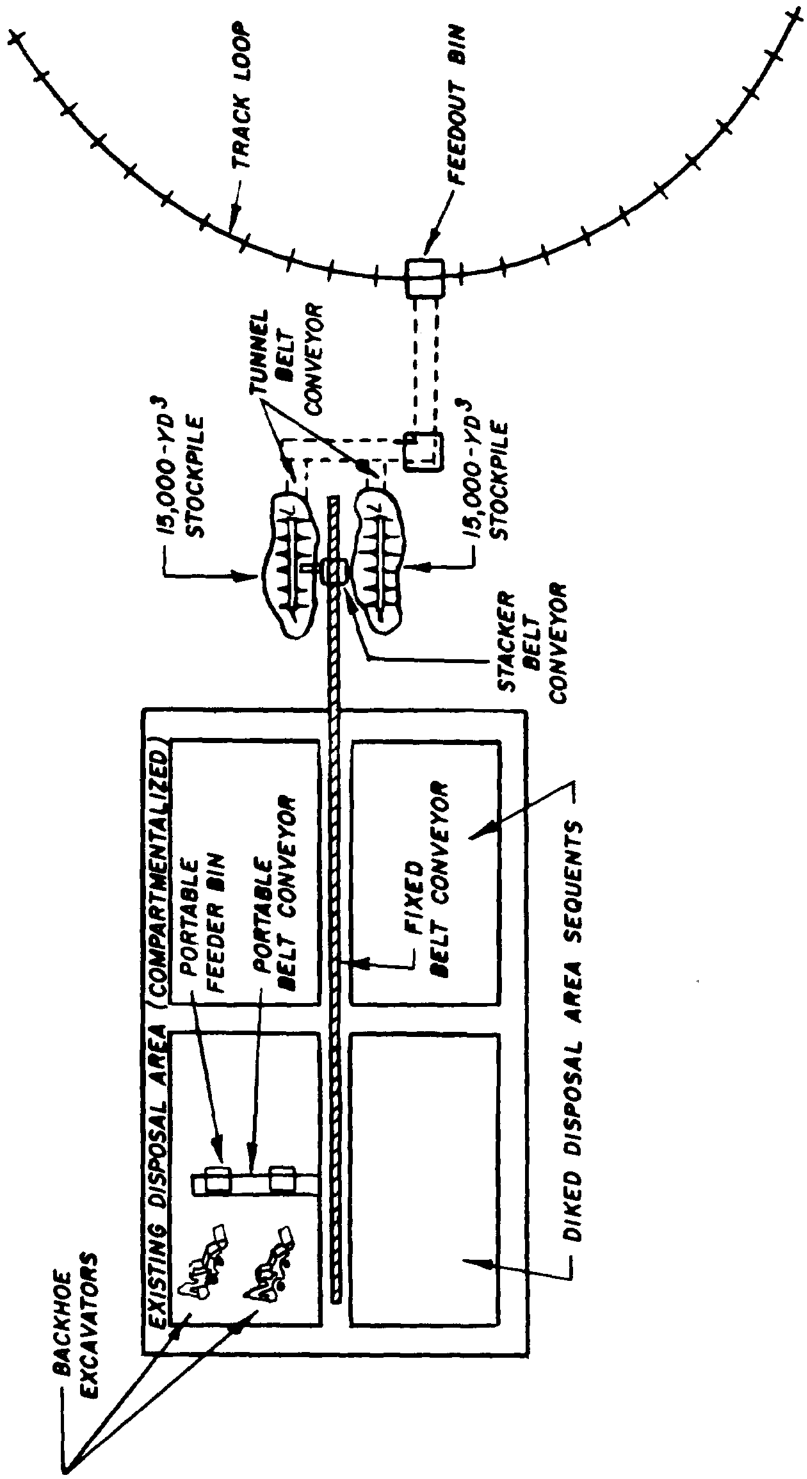


Figure 3-6. Unit train rail loading facility

upon disposal area size, equipment selected, type of access available, and frequency of trenching operations. A preliminary trenching program is developed from crust formation estimates, equipment operational characteristics (from Table 3-1), and trenching cycle intervals (from Table 3-2). Total cost may be estimated from computing equipment operating hours plus factors for nonproductive activities (30 percent is a good estimate), mobilization/demobilization, and administrative costs.

b. Transport costs. Transport cost can account for 90 percent or more of total land improvement and beneficial use budget costs. The cost figures presented in this section are meant to serve as examples for planning and do not represent definitive cost estimates. Table 3-3 is included to provide insight into the cost relationships for various modes of transport. The table provides total system costs for all five transport modes. Transport costs are reported in dollars per cubic yard of dredged material moved. This breakdown shows that economic feasibility is limited by distance for most transport modes. This table also shows the economies of scale for larger annual volumes of material shipped. Real estate and right-of-way costs for the hydraulic pipeline system are not included in the cost-estimating procedure.

Table 3-1

Operational Characteristics of Trenching Equipment

Equipment	Crust Thickness, in., for Effective Operation Minimum	Maximum	Maximum Trench Depth, in.	Approximate Trenching Rate, lin ft/hour	Approximate Rental Cost* $/hour
RUC	0	12	18	2,000+	75-100
Low-ground-pressure tracked vehicle + rotary trenchers	4	24	24	2,000+	35-45
Small dredge	4	10	30	25	50-75
Amphibious dragline	6	18**	Crust + 18	40	50-70
Small dragline on double mats	12	18	Crust + 18	30	35-50
Medium dragline on double mats	12	18	Crust + 18	40	40-50
Small dragline on single mats	18	24+	Crust + 18-24	50	35-45
Medium dragline on single mats	18	30+	Crust + 18-24	60	40-50
Large dragline on single mats	24	36	Crust + 24	80	45-55

Note: a. Vehicle or mat ground pressure must also satisfy critical layer RCI mobility criteria.
b. Low-ground-pressure tracked vehicle assumed to pull drag plow with point set only 1 or 2 in. below existing crust.
c. More exact definitions of dragline equipment given in text.

* Southeastern United States, 1977.

** Above this crust thickness, conventional dragline is usually more efficient.

\+ Between 24- and 30-in, crust thickness, use single mats.
Increase rates 10 lin ft/hour if dragline is working from perimeter dike.

Table 3-2

Estimated Interval Between Trenching Cycles for Various Equipment Items in Fine-Grained Dredged Material

Equipment Item	Equipment Location in Disposal Area	Initial Condition of Disposal Area Surface	Estimated Trenching Interval
RUC	Interior	Decant point	Each 2 weeks for first month, monthly thereafter
RUC	Interior	Crust ≥ 2 in.	Monthly
Low-ground-pressure tracked vehicle + rotary trencher	Interior	Crust ≥ 4 in.	Monthly
Small dredge	Interior	4 in. < crust – 10 in.	4 months
Amphibious dragline	Interior	Crust ≥ 6 in.	4 months
Conventional dragline	Interior	Crust ≥ 12 in.	4 months
Conventional dragline	Perimeter	Decant point	Monthly for first 3 months, bimonthly for next 3 months, 4 months thereafter
Conventional dragline	Perimeter	2 in. < crust < 6 in.	Bimonthly for first 4 months, 4 months thereafter
Conventional dragline	Perimeter	Crust ≥ 6 in.	4 months

Table 3-3

Comparison of Costs of Various Transport Systems, Quantities, and Distances**

Annual Quantity yd^3	Transport Distance miles	Cost, $\$/yd^3$, for Cited Transport System: Pipeline	Rail	Barge	Belt	Truck
500,000	10	2.47	*	2.47	8.98	4.57
	20	3.14	*	3.14	15.15	6.61
	100	9.54	7.18	4.71	*	13.69
	250	*	9.32	7.41	*	*
1,000,000	10	1.46	*	2.92	5.39	3.73
	20	1.91	*	3.14	13.47	4.19
	100	6.45	5.39	4.49	*	12.91
	250	*	7.58	7.18	*	*
3,000,000	10	0.79	*	2.70	2.25	3.17
	20	1.12	*	2.92	3.93	3.56
	100	4.10	4.21	4.49	*	12.35
	250	*	5.34	7.35	*	*
5,000,000	10	0.67	*	2.81	1.68	3.05
	20	0.90	*	2.92	3.14	3.42
	100	3.48	4.04	4.38	13.58	12.07
	250	*	6.06	7.07	*	*

* Indicates not competitive economically.
** These costs were taken from item 57 and are adjusted to March 1978 dollars.

CHAPTER 4

HABITAT DEVELOPMENT

4-1. Definition and Application. Habitat development refers to the establishment and management of relatively permanent and biologically productive plant and animal habitats. The use of dredged material for habitat development offers a disposal technique that is an attractive and feasible alternative to more conventional disposal options. Various habitat development alternatives and their applicability to disposal operations and sites will be discussed in this section. Within any habitat, several distinct biological communities may occur. For example, the development of a dredged material island may involve a wide variety of habitats (Figure 4-1). Four general habitats are suitable for establishment on dredged material:

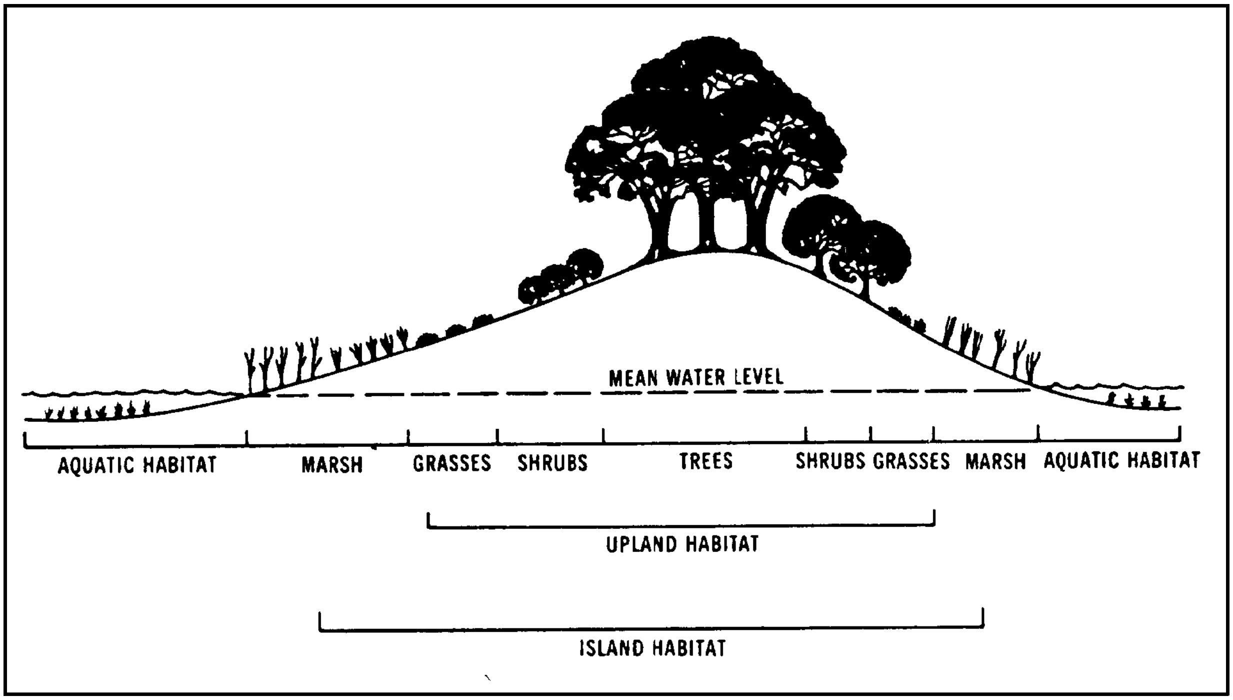


Figure 4-1. Hypothetical site illustrating the diversity of habitat types that may be developed at a disposal site

a. Wetland. Wetland habitat is a very broad category of periodically inundated communities, characterized by vegetation which survives in wet soils. These are most commonly tidal freshwater and saltwater marshes, relatively permanently inundated freshwater marshes, bottomland hardwoods, freshwater swamps, and freshwater riverine and lake habitats.

b. Upland. Upland habitat includes a very broad category of terrestrial communities, characterized by vegetation which is not normally subject to inundation. Types may range from bare ground to mature forest.

c. Aquatic. Aquatic habitats are typical submerged habitats extending from near sea, river, or lake level down several feet. Examples are tidal flats, oyster beds, seagrass meadows, fishing reefs, clam flats, and freshwater aquatic plant beds.

d. Island. Islands are upland and/or high zone wetland habitats distinguished by their isolation and particular uses, and completely surrounded by water or wetlands.

These concepts and their implementation are discussed in detail in items 19, 32, 51, and 72 and in Chapters 5-8 of item 73.

4-2. Case Studies of Selected Habitat Development Sites. Numerous examples of habitat development using dredged material substrates exist; nearly 1,000 are listed in Appendix C and four are presented here to show the diversity of such sites.

a. Buttermilk Sound Salt Marsh.

(1) Buttermilk Sound, a 5-acre intertidal island marsh located in the Altamaha River, Georgia, was created by plantings during 1975-76 on a sandy, infertile dredged material island which had not revegetated since deposition of material a number of years ago. Success of the original plantings was related to the period of tidal inundation and type of propagule. Sprigs were more successful than seeds, and smooth cordgrass was the most successful species planted (item 19).

(2) From the outset, this marsh site has been very successful (Figure 4-2). Since 1979 it has been visually indistinguishable from natural reference marshes. Although tidal scouring initially washed out plantings and eroded the lower part of the intertidal zone, the site quickly stabilized. The established plant community has trapped large amounts of fine material, resulting in a thick layer of silt that now covers the original substrate. Smooth cordgrass dominates the entire lower two-thirds of the intertidal zone. Swards of big cordgrass and saltmeadow cordgrass remain at the middle elevations where they had been planted. The Buttermilk Sound site differs from nearby natural marshes by possessing greater plant species diversity at lower elevations. This is probably due to plant species that were introduced in zones lower than those at which they would naturally occur. Aboveground biomass is similar to natural marshes, but belowground biomass is less. Wildlife use of the marsh is greater than in the natural marshes in all respects, including white-tailed deer, alligators, clapper rails, tern nesting, and migratory shorebird and waterbird use (item 59).

Figure 4-2. Buttermilk Sound habitat development field site, Altamaha River, Georgia, after 6 years of development

Figure 4-3. Salt Pond 3 habitat development field site, South San Francisco Bay, California, after 5 years of development

(3) In 1985, the Buttermilk Sound site continues to represent one of the most successful marshes built by the CE. It appears to be very stable and the marsh area, especially in the upper marsh zone, continues to increase coverage and density to the extent that only one bare sandy spot remains on the entire island. This spot was not shaved down from the original elevation to an intertidal zone, and therefore has been very slow to vegetate.

b. Salt Pond 3 Salt Marsh.

(1) Salt Pond 3, a marsh site is South San Francisco Bay, California, was established on a portion of a 100 acre saltwater evaporation pond that was partially filled hydraulically with clayey dredged material in 1974. It is the only nonisland habitat development site that has been built by the CE. Plantings of Pacific cordgrass and pickleweeds were established during 1976-77. Cordgrass sprigs successfully colonized the lower two thirds of the intertidal zone, and pickleweeds rapidly and naturally colonized the upper one-third (item 59) (Figure 4-3).

(2) The plantings maintained themselves and have spread slowly into adjacent unvegetated areas. Production is somewhat less than in nearby natural marshes, perhaps due to the relatively early stage of site succession. The lower cordgrass zone appears visually equivalent to natural marshes, and the entire 100 acres with the exception of an occasional small mudflat and the tidal channel have become densely vegetated (item 59).

(3) Wildlife use is predominantly by birds, especially shorebirds which feed along the channel, and terns and other waterbirds. Peregrine falcons and other raptors frequent the area and feed on songbirds and rodents in the upper marsh zone. This site appears to be stable and has survived the excessive rainfall and severe storms that pounded the west coast in 1983 without apparent damage. The rainfall actually seemed to improve appearance of the marsh by increasing growth in the upper marsh zone.

c. Gaillard Island Confined Disposal Facility.

(1) Gaillard Island, a new diked disposal island in lower Mobile Bay, Alabama, was built in 1981 by the Mobile District (Figure 4-4). The large, triangular-shaped island is being filled with material from the main shipping channel, and its gently sloped dike is primarily silty clay. Waves come into the island dike from all three sides, and erosion is a continuing problem. In 1981, smooth cordgrass was planted on the northwest dike behind temporary breakwaters made of floating and fixed tire breakwaters. Surviving plantings from 1981 grew and spread behind the breakwater, and more plants were set in 1982 with more breakwater designs and tests. Many of these were thriving in 1983 in spite of severe storms in the area over 1982-83 (item 2). Plantings in 1983 and 1984 were primarily coupled with tests of several filter materials and tire configurations, as well as burlap rolls, different size propagules, and various placements in the intertidal zone.

Figure 4-4. Gaillard Island habitat development field site, Lower Mobile Bay, Alabama, after 3 years of development

Figure 4-5. Bolivar Peninsula habitat development field site, Galveston Bay, Texas, after 6 years of development

(2) On the upland portion of the dike, aerially seeded Bermuda grass now dominates, and it has effectively stabilized large portions of the dike. Diversity of invading plant species is increasing, and this colonization process is expected to accelerate over time. Plant succession is already progressing, as areas that were weedy annuals in 1982 are now perennial grasses. Species diversity and populations of both plants and animals increase with each seasonal data collection period; these have been documented since 1981 and will continue to be noted, at least through 1987 (item 2).

(3) Twenty bird species are now nesting on the island; in 1984, 1985, and 1986 the birds numbered approximately 16,000 each year. Laughing gulls dominated the nesting areas; however, large numbers of seven tern species, black-necked stilts, and black skimmers nested with apparent success. Muskrats colonized the island in late 1985; land birds nested there for the first time in 1984. Brown pelicans are nesting on Gaillard Island, and 1983 marked the first recorded nesting for the species in Alabama in this century. In 1983, two chicks fledged from a single successful nest. In the 1984 summer survey, nests had increased to eight; 133 active nests were observed in 1985. In 1986, there were over 200 active nests by May, with more being built. In addition, large numbers of nonbreeding white and brown pelicans are living year-round at Gaillard Island (item 42).

d. Bolivar Peninsula Upland and Marsh Site.

(1) The Bolivar Peninsula field site is located on Goat Island in eastern Galveston Bay, Texas, and includes both marsh and upland planted areas. The original site is 20 acres of sandy dredged material, protected by a sandbag dike and a fence. It was built by the CE and planted in 1976-77. Both smooth and saltmeadow cordgrasses established well on this site (Figure 4-5). In the upland area, shrubs, trees, and upland grasses initially established well, but invasion by other species eventually crowded them out (item 2). Since initial establishment, smooth cordgrass has spread throughout the lower tidal zone and dominates the site. The saltmeadow cordgrass has spread throughout the upper intertidal zone, and has also spread into the upland section of the site. Saltgrass and pickleweeds have invaded the same zone (item 2).

(2) Oysters had densely colonized the dike area by 1982 and now help serve as a breakwater for the marsh. The site has also been heavily colonized by fiddler and blue crabs and has much fish use during high tide. Wildlife use is quite good; large numbers of sea and wading birds use the site. Small mammals live inside the fence that was once built to exclude them, and a number of ground nesting birds use the site. By 1983, conversion of the upland zone from prairie grasses and woody plants to high marsh plants was complete. Cover on the site is dense, and unless it becomes heavily grazed by ranging feral goats on the island, should remain in that condition (item 59). Clapper rail use is also quite heavy (item 42).

(3) Four adjacent dredged material sites are now being compared on Goat Island: the old site planted in 1976-77; a new deposit (1982) to the west of the old site being planted to test two breakwater designs built of low-cost materials; a second new deposit (1982) on the east side of the old site that is serving as a control; and a part of the old site that was covered with a new application of sandy dredged material in January 1986. Part of the original planting was deliberately covered with dredged material to determine the impacts of smothering, and to determine how rapidly a salt marsh could recover from such disturbance. It will also be compared to a site in East Matagarda Bay where silty dredged material was placed in August 1986 over existing high marsh. Data will be collected on these four areas at least through 1987 (item 42).

(4) The Bolivar Peninsula site survived a direct hit by two hurricanes in 1983 and 1986. The only noticeable change was the washing away of the protective fence in the bay in front of the site. All of the natural marshes with which it was compared were changed by washouts of pockets of marsh that created open-water pockets. These types of washouts did not occur on the field site (item 42).

4-3. Habitat Development Selection Process. The diversity of biological communities indicates the potential diversity of alternatives available under habitat development. This wide range of options will usually make using quantitative measures for selecting specific alternatives impractical, and consequently, selecting a given habitat development alternative is likely to be highly judgmental. The best determination will be made by a combination of local biological and engineering expertise and public opinion. Guidelines for the evaluation of individual habitat development situations are summarized below.

a. Conditions Favoring Habitat Development.

(1) The selection of habitat development as a disposal alternative will be competitive with other disposal options and types of beneficial uses when one or more of the following conditions exists:

(a) Public/agency opinion strongly opposes other alternatives.

(b) Recognized habitat needs exist.

(c) Enhancement measures on existing disposal sites are identified.

(d) Feasibility has been demonstrated locally.

(e) Stability of dredged material deposits is desired.

(f) Habitat development is economically feasible.

(g) Extensive quantities of dredged material are available.

Since disposal alternatives are often severely limited and constrained by public opinion and/or agency regulations, with constraints on open-water and other sites, disposal habitat development will be an attractive alternative, and in many cases will have strong public appeal. The need for restoration or mitigation or the need for additional habitat may strongly influence the selection of the habitat development alternative. This is particularly applicable in areas where similar habitat of considerable value or of public concern has been lost through natural processes or construction activities, such as at Pointe Mouillee in Lake Erie. Habitat development may be used as an enhancement measure to improve the acceptance of a disposal technique. For example, seagrass may be planted on submerged dredged material, or wildlife food plant established on upland confined disposal sites. Habitat development has considerable potential as a low-cost mitigation procedure and may be used to offset environmental impacts incurred in disposal.

(2) The concept of habitat development is more apt to be viewed as a feasible alternative if it has been successfully demonstrated locally. Even the existence of a pilot-scale project in a given locale will offset the uncertainties often present in the public and in resource agencies' perception of an experimental or unproven technique. The vegetation cover provided by most undiked habitat alternatives will generally stabilize dredged material and prevent its return to the waterway. In many instances this aspect will reduce the amount of future maintenance dredging necessary at a given site and result in a positive environmental and economic impact.

(3) The economic feasibility of habitat development should be considered in the context of long-term benefits. Biologically productive habitats have varied but unquestionable value (i.e., sport and commercial fisheries) and are relatively permanent features. Consequently, habitat development may be considered a disposal option with long-term economic benefits that can be applied against additional costs that may be incurred in its implementation. Habitat development may be particularly economically competitive in situations where it is possible to take advantage of natural conditions or where minor modifications to existing methods would produce desirable biological communities. For example, the existence of a low-energy, shallow-water site adjacent to an area to be dredged may provide an ideal marsh development site and require almost no expenditure beyond that associated with open-water disposal. Actual dollar values assigned to habitat development has been a controversial topic of discussion among scientists for a number of years. All agree that it has to be done, and that such sites are highly valuable; none agree on valuation estimates.

b. Guidelines. Habitat development presents several options ranging from establishment of upland communities to the development of seagrass meadows. A broad procedural guide to the selection of the habitat development alternative is given in Figure 4-6. The beneficial use planner should ignore categories unrelated to the particular problem, and may wish to add key site specifications.

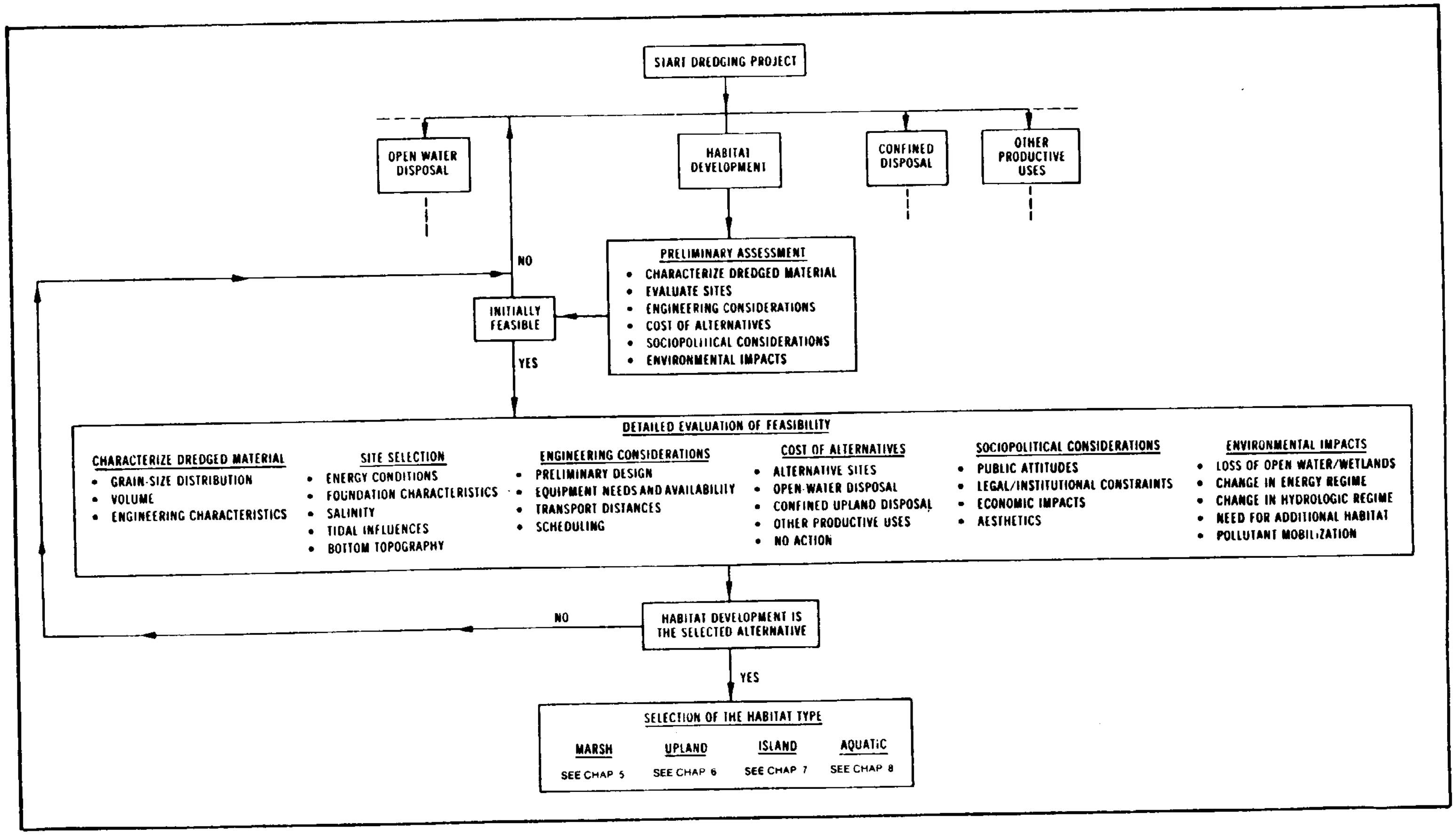


Figure 4-6. Procedural guidelines for selection of habitat development alternatives

(1) Preliminary assessment. The initial consideration of habitat development as a disposal alternative should include a preliminary assessment of feasibility, which involves judgment based on available data. A determination that habitat development is not initially feasible should be based on compelling negative evidence and not merely on a lack of information or specific precedents. In the absence of such negative evidence, one should proceed to the detailed evaluation of feasibility. Factors may arise at several stages in the evaluation that would lead to a determination of infeasibility. Should that occur, other disposal alternatives would be reconsidered.

(a) The detailed evaluation of feasibility includes six major categories beginning with a characterization of the dredged material and arranged generally in the order of need for acquisition of information. In characterizing the dredged material, the physical, chemical, and engineering characteristics of the material to be dredged should be determined. These properties will help define the general considerations of site selection.

(b) Site selection should be based on an adequate knowledge of energy conditions, foundation characteristics, salinity, tidal influences, and bottom topography. Energy conditions will largely influence the feasibility of establishing a stable substrate, or the necessity of protection structures. Foundation characteristics will determine the ability of a given site to support construction activities or structures. Salinity and tidal influences will dictate the plant species composition. A more detailed analysis of these factors will be necessary later for detailed design purposes if the habitat development alternative is selected, but even in this early phase, some field sampling may be necessary if general information is not available.

(c) Engineering considerations at this stage are largely confined to preliminary designs and an assessment of equipment needs and availability. Details such as scheduling to meet critical environmental dates (e.g., spring or summer planting times) and the identification of dredged material transport distances will provide useful planning data. In many projects, the pivotal determination of engineering feasibility or infeasibility can be made at this stage.

(d) Evaluation of the cost of alternative disposal methods is the next essential step. In a number of CE Districts, this is the first step in assessment. Detailed economic analyses must await the further development of design criteria; however, a general cost comparison of the various alternative sites should be possible at the completion of the preliminary assessment of feasibility. This is another critical step because considerable time and effort can be spared by defining the economic limits that the project must satisfy to remain competitive with other alternatives.

(e) Of the sociopolitical considerations, public attitudes and legal and institutional constraints are most likely to prove limiting. Negative public attitudes generally occur when the community views the proposed habitat as a threat to established values. Legal and institutional constraints frequently arise when there are unanswered questions of ownership and access or when local interests have designated the site for an alternative future use. Direct economic impacts may be identified if the habitat to be developed may alter important shellfishing or recreational areas or block a water view.

(f) The environmental impact of most habitat development projects may be expressed as a loss of open-water habitat or wetland systems and changes in hydraulic and energy regimes. The impacts of these factors tend to be cumulative and are directly related to the perceived need for additional habitat. In general, the need for more habitat is considered more critical in areas that have lost or are losing considerable habitat of that type. Pollutant mobilization by plants growing on contaminated dredged material might be of concern, and its potential should be determined prior to habitat development.

(2) Selection of habitat development as an alternative. Upon completion of the preliminary assessment of feasibility, a determination can be made whether habitat development is applicable. If habitat development is a selected alternative, a decision regarding the type or types of habitats to be developed must be made. This decision will be largely judgmental, but in general, site peculiarities will not present more than one or two logical options. Specific advantages and disadvantages likely to be encountered are evaluated, and items of particular concern during early feasibility determinations are highlighted in Chapters 5, 6, 7, and 8.

CHAPTER 5

WETLAND HABITATS

5-1. Marshes. Marshes are considered to be any community of grasses or herbs that experience periodic or permanent inundation. Typically, these are intertidal freshwater or saltwater marshes and periodically inundated freshwater marshes. Marshes are recognized as extremely valuable natural systems and are accorded importance in food and detrital production, fish and wildlife cover, nutrient cycling, erosion control, floodwater retention, ground-water recharge, and aesthetics. Marsh values are highly site-specific and must be examined in terms of such variables as species composition, location, and extent, which in turn influence their impact upon a given ecosystem.

5-2. Marsh Development Considerations. Accurate techniques have been developed to estimate costs and to design, construct, and maintain man-made marsh systems (items 2, 19, 42, and 59). Methods are available to predict the impact of the alternatives on the environment and to describe the value of the proposed resource prior to its selection.

a. Advantages. Several advantages have been found in marsh development as a disposal alternative:

(1) Considerable public appeal.

(2) Creation of desirable biological communities.

(3) Considerable potential for enhancement or mitigation.

(4) Frequently a low-cost option.

(5) Useful for erosion control.

Marsh development is a disposal alternative that can generate strong public appeal and has the potential of gaining wide acceptance when some other techniques cannot. The created habitat has biological values that are readily identified and accepted by many in the academic, governmental, and private sectors. However, application requires an understanding of local needs and perceptions and the effective limits of the value of these ecosystems. The potential of this alternative to replace or improve marsh habitats lost through dredged material disposal or other activities is frequently overlooked. Marsh development techniques are sufficiently advanced to design and construct productive systems with a high degree of confidence, even in moderate wave energy environments. For example, salt marshes have been established at Bolivar Peninsula, Texas, and Gaillard Island, Alabama, behind temporary breakwaters in moderate energy areas. These habitats can often be developed with very little increase in cost above normal project operation, a fact attested to by hundreds of marshes that have been inadvertently established on dredged material and by the more than 130 marshes that have been purposely created using dredged material substrates in U. S. waterways.

b. Disadvantages. Several problems are likely to be encountered in marsh development:

(1) Unavailability of appropriate sites.

(2) Loss of other habitats.

(3) Release of contaminants.

(4) Loss of site for subsequent disposal.

By far the most difficult aspect of the application of marsh development is the location of suitable sites. Low energy, shallow-water sites are most attractive; however, cost factors will become significant if long transport distances are necessary to reach low energy sites. Temporary protective structures may be required if low energy sites cannot be located and have been successful at several Gulf coast sites where moderate wave energy occurs (items 1 and 2). Marsh development frequently means the replacement of one desirable habitat with another, and this will likely be the source of most opposition to this alternative. There are few reliable methods for comparing the various losses and gains associated with this habitat conversion; consequently, determining the relative impact may best be made on the basis of the professional opinion of local authorities. Although studies have shown that contaminant uptake from soil in marsh environments is minimal, the planner should remain alert that the potential exists with highly contaminated sediment use. Development of a marsh at a given site can prevent the subsequent use of that area as a disposal site. In many instances, additional development on that site would be prevented by state and Federal resource agencies. Exceptions may occur in areas of severe erosion or subsidence, or where previous disposal created a low marsh and subsequent disposal would create a higher marsh.

c. Maintenance. Dredged material marshes should be designed to be relatively maintenance free. The degree of maintenance will largely depend on the energy conditions at the site, a factor that should be included in the cost analysis of the project. No maintenance may be required to protect the new marsh in low energy situations. In areas of somewhat higher energy conditions, protection may be required only until the marsh has a chance to mature. In those areas, protective structures may be designed for a relatively short life with no additional maintenance required. In high energy situations, perpetuation of the marsh may require planned periodic maintenance of protective structures and possibly periodic replanting.

5-3. <u>Guidelines for Marsh Development</u>.

a. Selection of Wetland Type. If marsh development is the beneficial use alternative selected, it is necessary to select the most appropriate wetland type (Figure 5-1). In most situations, the selection of a wetland type will be largely predetermined by overriding environmental conditions such as tidal range salinity or flood conditions. Most marsh development projects, simply because of the nature of dredged material disposal and the formation of drainage patterns, will contain elements of shallow and deep marsh (freshwater) or high and low marsh (saltwater).

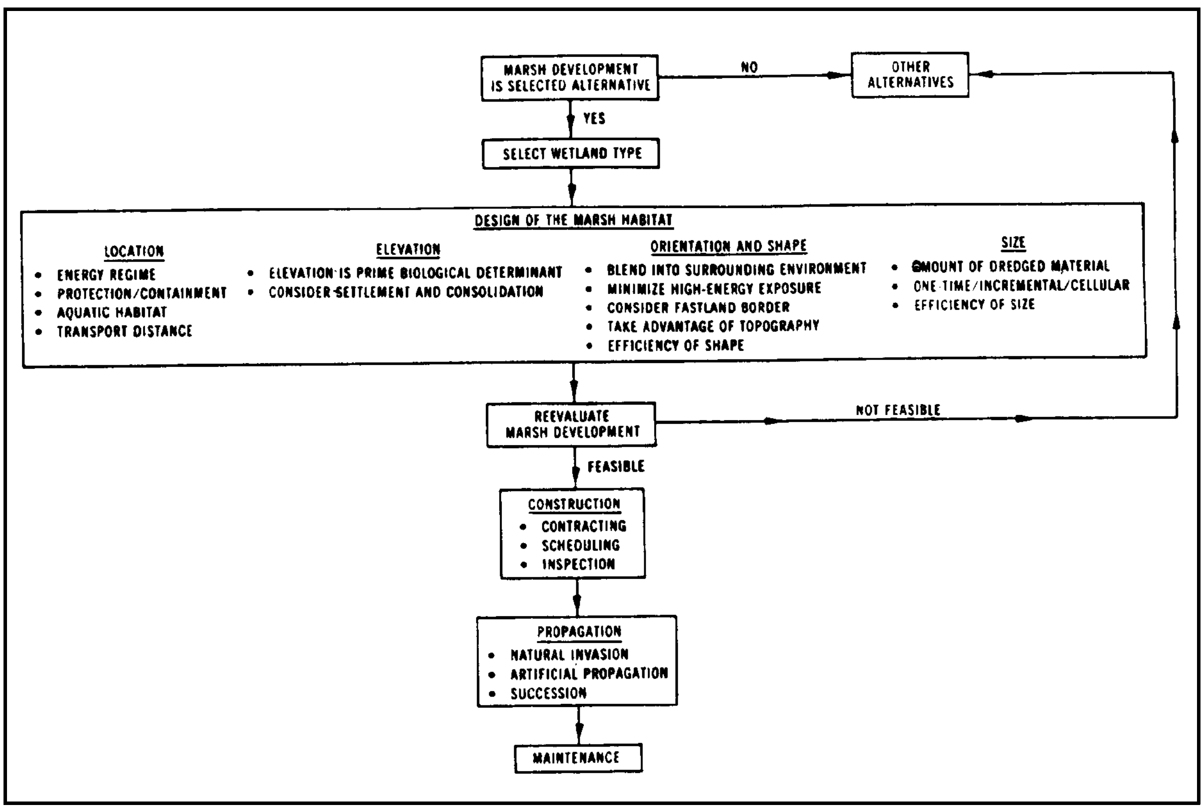


Figure 5-1. Procedural guidelines for selection of marsh habitat development

b. Design of Marsh Habitat. The detailed design of the marsh habitat is separated into four parts: location, elevation, orientation and shape, and size. The design should maintain the goals of disposal of dredged material through the development of a desirable biological community, using the most cost-efficient methods and causing a minimum of environmental perturbation. Engineering and biological designs of marshes have been researched and field tested by WES (items 19 and 59) in a number of locations.

(1) Location. The location of the new marsh may be the most important decision in marsh development. Low energy areas are best suited for marsh development, and sandy dredged material has been found to be the ideal substrate. Departure from these conditions will require a careful evaluation of the need for structural protection and containment. High wave or current energies may prevent the formation of a stable substrate and the establishment of vegetation, making various forms of protective structures or mechanisms necessary (item 2). Another major consideration in the protection/containment equation is the grain-size distribution. Hydraulically placed clay will usually require temporary or permanent containment, regardless of wave or current conditions. Containment is generally required to hold fine-grained type material within a prescribed area. Silt under very low energy situations may require no containment or protection; however, in moderate energies it is essential. Sand that would require no protection under low energy situations may require some protection under moderate wave energy. Obviously, a wide range of conditions exists. It should be remembered that those areas best suited for marsh development (shallow, low energy) are also likely to be biologically productive. Particular efforts should be made to avoid unusually productive areas such as seagrass meadows, clam flats, and oyster beds. In general, the further dredged material must be moved, the greater the cost in marsh development. The availability of suitable equipment may also influence the feasibility of distant disposal. Therefore, attention should be given to locating the disposal site as near the dredging operation as possible.

(2) Elevation. Final elevation of the marsh substrate is largely determined by settlement and consolidation and is the most critical of the operational considerations, as it dictates both the amount of material disposed and the biological productivity of the habitat established. Techniques are available to predict the final stable elevation of a given volume of dredged material placed in a confined intertidal situation (item 19). Salt marshes are generally most productive within the upper third of the tidal range, while freshwater marshes should generally be flooded to a depth of not more than 2 feet. Determination of final elevation is critical and should be based on precise knowledge of the elevational requirements of the plant community. Variation in topography will produce habitat diversity and should be encouraged, provided that the majority of the area is within the desired elevation range. If the possibility of not being able to achieve a desired elevation appears likely, incremental filling may be possible, with a conservative estimate of the amount of material necessary to attain a given elevation. Should the final elevation still be too low, the difference can be made up in subsequent disposal. If one-time disposal is anticipated, it may be

possible to overfill and rework the area to a lower elevation with earth-moving equipment,

(3) Orientation and shape. The orientation and shape of the new marsh will largely determine its total cost, its efficiency as a disposal site, and its effectiveness as a biological addition to the natural environment. The shape should minimize impact on drainage or current patterns in the area surrounding the disposal site and allow it to blend into the surrounding environment. If high energy forces are anticipated, the marsh should be shaped to minimize high-energy exposure. Such design will reduce the threat of failure and reduce the cost involved in providing protection. If available, a fast-land border, such as a cove, island, or breakwater, can serve as low cost protection and minimize the length of otherwise necessary and costly containing or protective structures. An effort should be made to take advantage of bottom topography during the design of the new marsh. Disposal sites are often not uniform in depth; if possible, protective structures should be located in shallow water and the fill area in deep water to maximize the containment efficiency. If dikes are built from local material, it may be possible to deepen the disposal area by locating borrow material within the dike area. Shape may also be a major cost determinant when diking is required. For a given area of protected marsh, a circle requires the minimum dike length. A rectangle increases dike length in proportion to its length-width ratio. For example, a rectangle ten times longer than wide requires a perimeter nearly twice that of a circle to contain the same area.

(4) Size. The size of the disposal area will be a function of the amount of the material to be dredged and the volume of the disposal area. There are several filling options that might affect size, including one-time, incremental, and cellular. One-time filling implies that a site will be filled and marsh established within that operation, and that the area will not be used again for disposal. In incremental filling it is recognized that the site will be used during the course of more than one dredging operation or season and the disposal area will be considered full when a predetermined marsh elevation is attained. In cellular filling, a compartment of a prescribed disposal area is filled to the desired elevation during each disposal project. Both incremental and cellular filling offer the efficiency of establishing a large disposal site and utilizing it over a period of years, thus avoiding repetitive construction, design, and testing operations. A major difference between these two methods is that the cellular method provides a marsh substrate at the end of each season, whereas many years may be required before incremental filling attains this goal. Cellular or incremental disposal sites would generally be larger than one-time disposal sites, and this increase in size may offer a more cost-effective disposal site.

c. Reevaluation and construction. A final reevaluation of the marsh development alternative should take place prior to construction. Marsh development contracting procedures may sometimes prove to be difficult because neither the contractors nor the CE may have had previous experience with marsh contracts. Prebid conferences to explain the intricacies of the project as well as carefully detailed contract specifications are strongly advised. Scheduling the dredging can prove to be particularly important. To obtain maximum vegetative cover within the first year, it is necessary to have the dredged material in place and with a relatively stable surface elevation by the beginning of the growing season. Delays will affect the initial success of the project and may result in loss of nursery or seed stock, replanting costs, adverse public reaction, and unwanted erosion at the site. It cannot be overemphasized that careful inspection of the disposal operation is <u>essential</u>, as the attainment of the prescribed elevation is critical, an aspect that may not be appreciated by the dredging crew.

d. Vegetation establishment. Propagation of marsh plants can be attained by natural invasion or artificial propagation. Natural establishment of plants can be expected if the environmental requirements for a marsh community, including a source of propagules, are present at a site. In some cases, especially in freshwater marshes, natural invasion will occur on a site within a few months; in others, especially saltwater coastal areas, many years may be required. The process of marsh establishment will be accelerated on most sites by seeding or sprigging. In the selection of species for artificial propagation, every effort should be made to ensure that the selected species represent a natural assemblage for a given area. Exotic or offsite species will not generally be able to compete with natural invaders. An exception may be an instance in which a species is selected for temporary cover or erosion control until natural invasion has colonized the site. For example, smooth cordgrass is planted in tropical Florida, with mangrove seed pods interspersed. The smooth cordgrass provides protection for the mangrove seedlings until they become firmly established. The advantage of propagation by natural invasion is the low cost, and this may be a pivotal consideration in borderline projects. The advantages of artificial propagation are more rapid surface stabilization and an immediate vegetation cover. Seven types of propagules are available for marsh vegetation establishment: seeds, rootstocks, rhizomes, tubers, cuttings, seedlings, and transplants (sprigs). By far the most commonly used in marsh establishment is transplanted sprigs.

(1) Factors influencing design. The successful establishment of a planned marsh requires careful project design and implementation. Each site will exhibit its own peculiarities and must be approached individually. In any marsh design, a number of factors are significant; the most important are salinity, tidal range, flood stages, soil texture, wave and wind action, contaminant tolerance, outside influences, and cost.

(2) Protection. The new substrate must be protected either by virtue of its location in a low energy area or by placement of a protective structure such as a permanent or temporary dike or breakwater (Figure 5-2). Low energy areas are most commonly found in the lee of beaches, islands, and shoals; in shallow water where wave energies are dissipated; on the inside downstream side of riverbends; in embayments where marshes presently exist; within zones of active deposition; and away from long fetch exposure, tidal channels, uncontrolled inlets, and headlands. Plants themselves may be used as a

Figure 5-2. A floating tire breakwater installed at Gaillard Island, Alabama, to protect newly planted marsh from moderate wave energies

Figure 5-3. Transplants at Miller Sands habitat development site, planted on 3-foot centers, at the end of the first growing season

protection barrier by planting more erosion-resistant large transplants on the outer fringes of the marsh, with more susceptible but less expensive propagules such as rootstocks, tubers, and seeds in the interior and high marsh areas of the site. Young plants are particularly vulnerable to wildlife feeding and browsing. Herbivores such as Canada geese, muskrats, nutria, rabbits, goats, sheep, and cattle can rapidly destroy a newly established marsh. Heavy grazing may even destroy mature marsh communities. Potential animal depredation should be evaluated for each site and, in extreme cases, should be controlled by trapping or fencing.

(3) Plant spacing. Plant spacing is highly site specific and is governed by the quality of the substrate, type of propagule, length of the growing season, and desired rapidity of plant cover. Generally, when transplants are used, parallel rows and spacings of 1 to 3 feet are recommended to achieve relatively uniform cover by the end of the second growing season (Figure 5-3). Planting at about 3-foot intervals is usually a good compromise between high costs and full cover. If the cost of transplants is a limiting factor, or there is no compelling reason to attain full cover within a short time, then spacing may be greater than 3 feet. If the site is extremely unstable, subject to heavy wildlife pressures or physical stresses, or if aesthetics are an immediate concern, more dense plantings may be desirable. For example, if Canada geese are known to use the area heavily, the plants should be spaced closely to encourage the geese to limit their feeding to the edges of the new marsh. Transplants may be evenly or randomly spaced; even spacing is more efficient in use of machinery and labor. Other vegetative propagule types such as rootstocks, rhizomes, and smaller sprigs are handled similarly to transplants. However, since they grow much slower initially, these propagules should be spaced more closely. Intervals of 1 foot are recommended for rootstocks and rhizomes, and 1 to 1.5 feet for smaller sprigs.

(4) Diversity. In general, a site planted in a variety of species over a topographic range, from deepwater to upland areas, is preferred. Exceptions to this are sites where physical stresses are particularly harsh or stabilization is critical (as on dike slopes), where only one species can tolerate the conditions, or where quick cover by a vigorous monoplanting, such as smooth cordgrass at low intertidal elevations, is needed. More typically, variation in site elevation with respect to water regime will necessitate planting the dredged material with at least two species to obtain both high and low marsh. Species diversity can be used to achieve greater appeal to a more diverse group of wildlife, to enhance habitat for a target wildlife species, to control animal depredation by planting a high-value wildlife food species as a sacrifice, to better ensure site success, and to provide for long-range plant succession at the site by making available sources of several desirable species. Generally, marshes of about 20 percent mudflats, 30 percent vegetation cover, and 50 percent open, shallow water are most productive from an ecological standpoint and in overall wildlife use. It may be necessary to first establish the marsh, then do any clearing that may be required for a wildlife enhancement objective.

(5) Plant species selection. The selection of plant species appropriate to the region, to the site, and to the project objectives is the first step toward vegetation establishment. Success of the project may hinge upon the species being planted, propagule types used, and the use of the plant material by wildlife. The site planner should familiarize himself with nearby marsh plant communities that occur on similar sites, noting the distribution and relative abundance of species within the stands. All species should be considered. Smooth cordgrass, because of its large areal extent, has been considered the major marsh species in the eastern and gulf coasts of the United States, but other species such as black needlerush, saltgrass, saltmeadow cordgrass, big cordgrass, saltmarsh bulrush, river bulrush, cattails, and nutsedges are also easily established and highly productive. Figures 5-4, 5-5, 5-6, and 5-7 show generalized profiles of major marsh plant associations for east and west coast salt marshes, brackish marshes, and fresh lake, pond, and river marshes. Selection of a species or mixed group of species for planting at a particular site should be based upon: project goals, location, climate and microclimate, tolerance, soil, plant growth habits, plant availability, maintenance requirements, and costs. If a project goal is to establish habitat for target wildlife species, any plant species known or suspected to be of use for cover, food, resting, or nesting for those species should be considered. If soil stabilization is a goal, species selection will be influenced. Marsh plant species have varied capacities for stabilization. Their underground root structure, rate of growth, and season of growth are important, and species with a longer growth cycle, such as smooth cordgrass and saltmeadow cordgrass, probably are more effective at erosion control than ones such as big cordgrass with a seasonal cycle.

(6) Propagule selection. Once species selection has been completed, more detailed consideration must be given to the type and availability of plant propagules, the amount of plant material needed to propagate a site, and the costs. The criteria for selection of propagule types are similar to the considerations used for selection of plant species: availability and costs, collection and handling ease, storage ease, planting ease, disease, urgency of need for vegetative cover, and site elevation.

(7) Handling plant material and planting the site. These techniques are generally those that will be applied by a CE contractor. Specific handling and planting details for marsh vegetation are discussed in items 19 and 39 for seeds and vegetative propagules such as transplant and rootstock. Appendix B provides information on 359 upland and 105 wetland plant species that may be planted on dredged material beneficial use sites.

(8) Pilot propagation study. In a marsh development project where there are unknown factors such as seed or sprig collection and planting techniques, effects of animal depredation, rate of plant spread, heavy metal uptake, or lack of experience in similar projects, it is prudent to conduct a pilot study. A pilot project is particularly advisable if the project is a large and costly one. A pilot study’s main purpose is to determine whether or not the selection plant species and propagules will grow under conditions

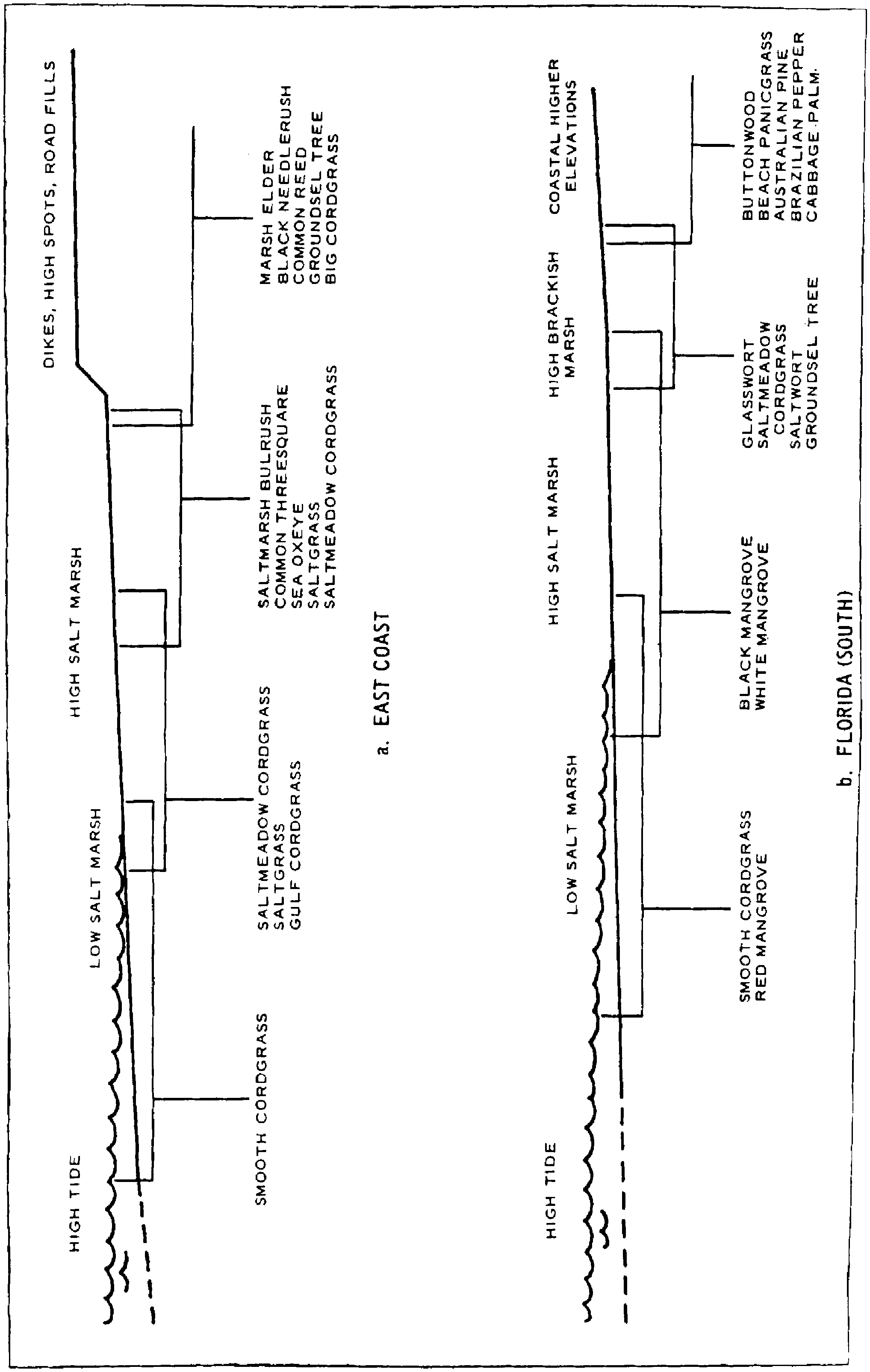


Figure 5-4. Sketches of typical east coast and Florida tidal marshes showing plant associations and usual occurrence in the marshes

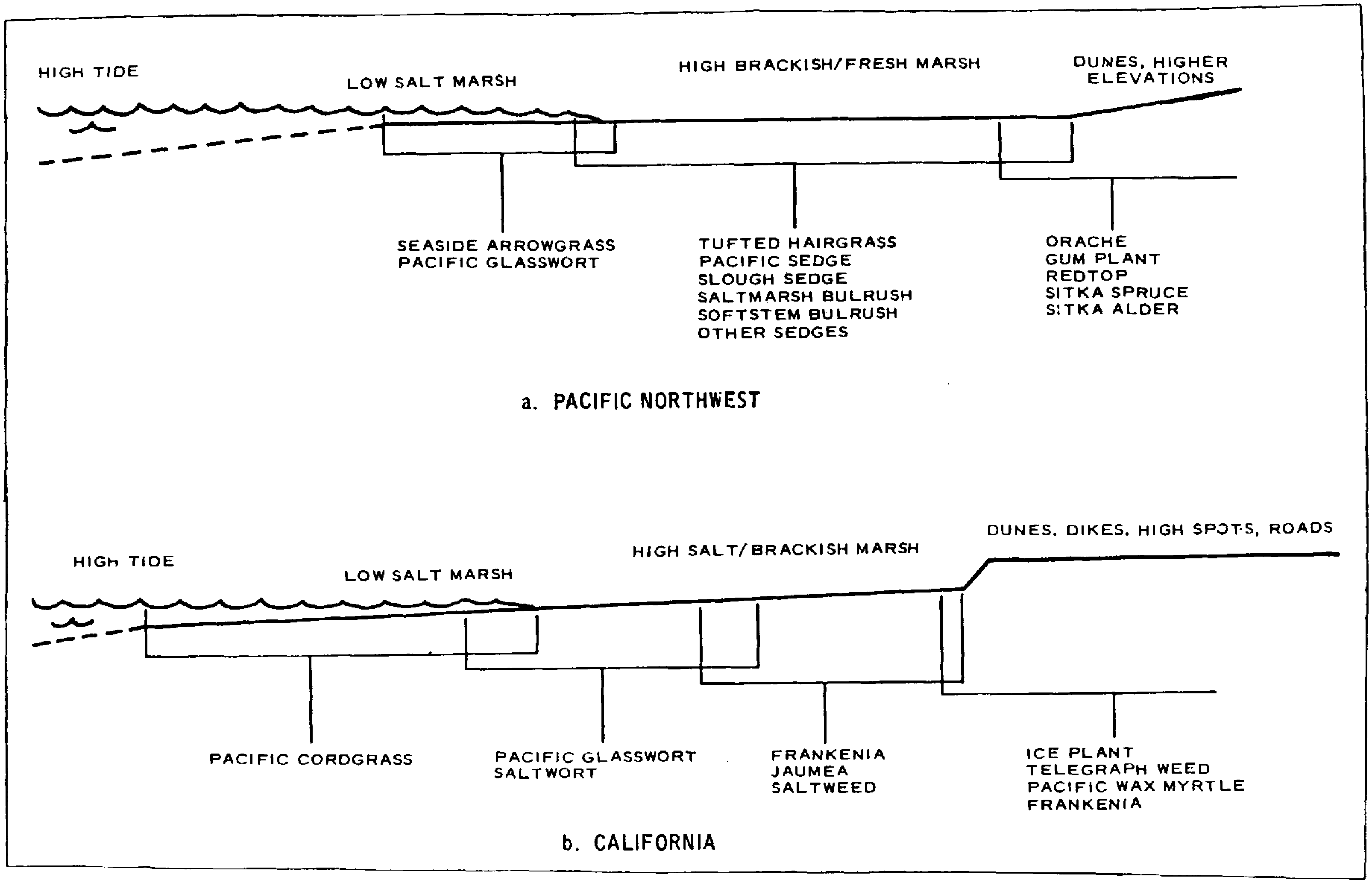


Figure 5-5. Sketches of typical Pacific Northwest and California Coast tidal marshes showing plant associations and usual occurrence in the marshes

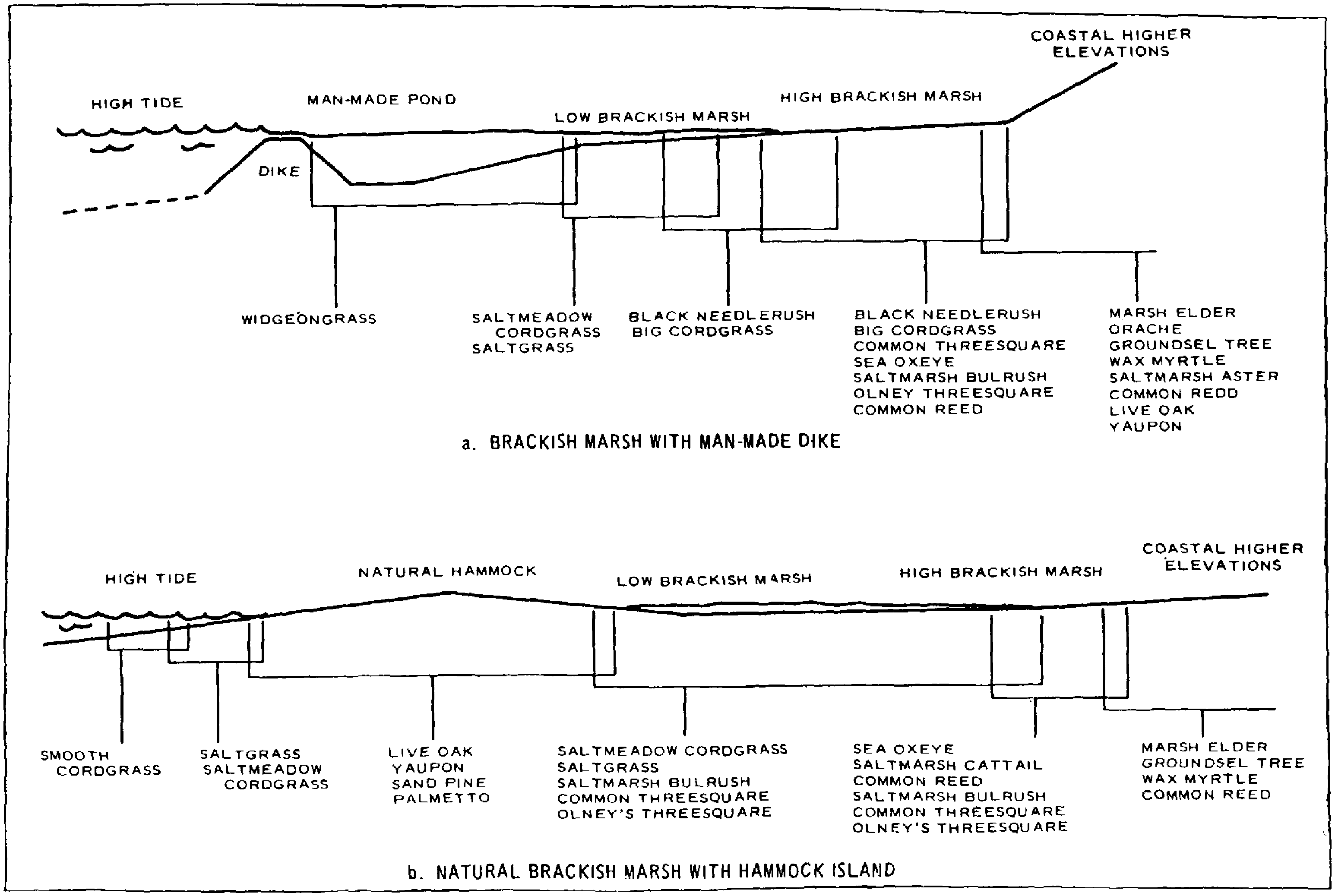


Figure 5-6. Sketches of typical brackish marshes showing plant associations and usual occurrence in the marshes

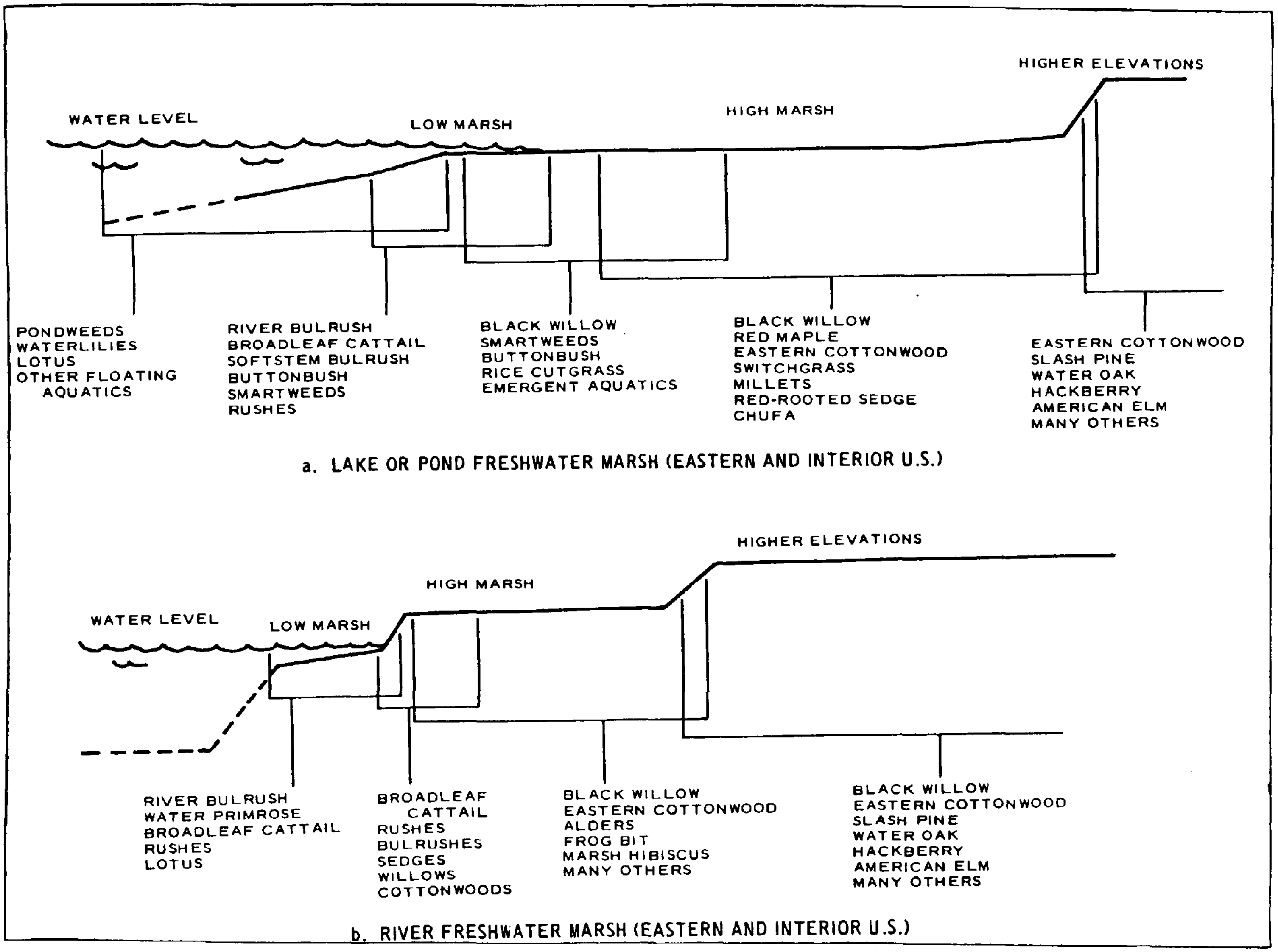


Figure 5-7. Sketches of typical lake or pond and river freshwater marshes showing plant associations and usual occurrence in the marshes

found on the site. The study can be conducted in less than a year, but the test species should be allowed to grow for one full season before conclusions are drawn. Such a project should be of sufficient size that it will accurately reflect future operational difficulties. Each selected species should be tested against all site conditions, and it may be advisable to test more than one propagule type, propagation method, planting time, and plant spacing for each species. The size of the pilot study is limited only by the desired tests, the time available for such testing, and funding. A simple statistical design will permit quantitative evaluation of the study where prediction of degree of success or failure can be made. The success of these plants can generally be evaluated by observation of survival. Test plots established should be evaluated on a regular basis to determine survival and growth, natural plant invasion, erosion, and animal depredation. Same-position photography on a regular basis is also valuable in obtaining a good record of plant success, growth, or dieback.

(9) Time of planting. Time of planting is very important regardless of the propagule type used. For example, seeds planted before the last frost in the spring may suffer heavy damage, and planting in midsummer may result in heat and drought stress of the seedlings as they sprout. Vegetative propagules may be planted when the ground is not frozen, and when the day temperatures average less than 68°F. With provisions for local climatic extremes and periods of severe storm or tide activity, propagules are best planted in early to midspring. Along the gulf and south Atlantic coasts, planting is recommended in all but the summer months. Fall planting, although a horticulturally acceptable practice, is not recommended for marshes as severe loss of propagules may result from erosion of sediments away from the root systems before regrowth begins the following spring. To lessen shock, propagules held in storage inside a nursery or greenhouse should not be planted until temperatures at the field site are at least as warm as the storage area. Propagules held in shady areas should be gradually acclimated to sunny conditions to prevent blistering and death of leaves. Propagules should also be acclimated to the salinity that exists at the site. For example, if saltmeadow cordgrass propagules are dug from a donor marsh of five parts per thousand (ppt) salinity to be planted in a marsh of higher salinity, they could be maintained at 5 ppt until about 2 weeks before planting when they should be moved to a solution of the same salinity as the accepting marsh. If there is a large difference of at least 10 ppt, gradual acclimation is necessary.

(10) Dredged material (soil) bed preparation and treatment. Initial dredged material assessment should have revealed certain characteristics of the substrate: texture, salinity, nutrient level, and potentially toxic levels of metals, pesticides, petroleum products, etc. These characteristics were considerations used to select species and propagules and now must be considered in the preparation of the soil bed and any treatments needed for planting such as liming and fertilizing. Actual plot preparation should take place just prior to planting of the site. Sandy dredged material disposal sites often can be graded to achieve desired slope and elevations. Fine-textured material cannot be easily modified once placed. Dewatered and

potentially acidic material may be encountered at higher elevations within the marsh development site. Modification of the pH of this dewatered material using some form of lime may be necessary if the pH is less than 5.5. Fine-textured dredged material seldom needs fertilizer, as it tends to be rich in nutrients. A positive short-term plant response generally can be obtained by fertilizing sandy material and it is usually recommended on highly erosive sites. However, long-term survival of the site may not be affected by fertilizer applications. In general, under marsh conditions of periodic inundation, fertilization is not recommended.

(11) Plants for dikes. Temporary or permanent dikes must often be erected to contain fine-textured dredged material. It may be advantageous to stabilize these with plants to reduce erosion. Representative plants that may be used successfully on dikes in coastal areas are saltmeadow cordgrass, saltgrass, groundsel tree, marsh elder, common reed, seaside goldenrod, beach panic grass, and coastal bermuda grass. These are established using agronomic upland practices discussed in Chapters 6 and 12 and in items 30 and 32. Dikes in interior and freshwater areas may be planted with species such as tall fescue, reed canary grass, giant reed, common reed, common Bermuda grass, and switchgrass. All these species may be seeded, and most are commercially available.

e. Potential Problems.

(1) Project timing. Dredging and biological calendars frequently do not match. There are two key items regarding biological scheduling: predictable lead time is necessary to prepare some propagule types, and planting is usually best in the spring. Transplants grown in a greenhouse cannot be held beyond a certain point .without greatly increasing costs and weakening the propagules. Similarly, seeds must be collected when they mature in the field and often will not remain viable for extended periods of time. Dredging schedules are often variable, particularly so when new disposal techniques are being employed. In almost all situations the dredging schedule will predominate; therefore, it is best not to initiate all planting preparations until dredging times are assured. In most situations a delay of 4 to 6 months between completion of dredging and propagation will be acceptable. If this is not acceptable, the dredging schedule should be adjusted if possible. Late summer dredging will usually result in a site being ready for propagation in the spring of the following year. It will often not be possible to dredge and plant in the same calendar year as both procedures are subject to time constraints and delays.

(2) Contaminant uptake by plants. Metals and chlorinated hydrocarbon compounds commonly associated with industrial, agricultural, and urban areas may be transferred to marsh plants from the air, water, or marsh substrate. When contaminated dredged material is used for marsh development, the potential for contaminant transfer should be considered. This potential problem has been discussed in Chapter 2.

(3) Invasion of nonpreferred plant species. In brackish or freshwater marshes, invasion of unwanted plant species such as purple loosestrife or common reed can occur readily if propagules of those species are already present nearby. The most frequent invader in the east and gulf coast areas with the exception of south Florida and Texas is common reed; in freshwater areas, broadleaf cattails may create dense stands. Although these two species have value for soil stabilization and wildlife use, they may grow in too dense a stand for maximum wildlife diversity and therefore require control. If the final elevation of a salt marsh substrate is higher than planned and relatively free of tidal inundation, common reed and more upland species may invade. In northern U. S. fresh marshes, purple loosestrife is developing into a major pest species. If it is at a higher elevation but tidal inundation still occurs, a high marsh may result when a low marsh was planned.

(4) Pests and diseases. Wildlife and feral animals of domestic breeds can destroy newly planted vegetation or retard succession by grazing or trampling. Grazing pressure varies among regions and situations. Potential control methods include fencing the site to exclude pests, trapping and removing pests, locating the site at a sufficient distance from pest sources, and planning the project to avoid a known pest problem. Infestations of harmful pests such as chewing insects and snails will cause occasional problems and should be dealt with, if necessary, as they occur. Pest prevention techniques should be tailored to the site. While plant diseases do occur among marsh species, healthy stands will generally not become heavily infected. Only in cases of severe infections should control measures be undertaken.

f. Postpropagation Maintenance and Monitoring. Monitoring of beneficial use sites is discussed in detail in Chapter 16. There are two major considerations in postpropagation phases of any marsh project: to maintain or not to maintain the site. Nonmaintenance has advantages of allowing natural succession to take place once the initial establishment is ensured and involves no additional expenditures. Disadvantages that could result from lack of maintenance include plant invasion by unwanted species, colonization by undesirable wildlife species, and major changes in site topography from climatic forces. Monitoring can determine the need for further soil treatment, to control for pests, to remove debris accumulations smothering plants, to make additional plantings, and to determine site progress and success.

5-4. Engineering Aspects of Wetland Habitat Development. Field investigations and laboratory tests required for sediment characterization and substrate design in marsh habitat development are similar to those required for design of conventional dredged material disposal areas. The term "substrate" here refers to the dredged material upon which a marsh will be developed. The elements of substrate design include configuration, elevation, protection, and retention. Required field investigations and laboratory tests as they pertain to habitat development in salt water or fresh water sites include channel investigations, site investigations, bottom topography, evaluation of wave and water energy, and substrate foundation investigations including consolidation and sedimentation. More detailed descriptions of certain procedures are contained in Palermo et al. (item 62). Engineering design of substrate for marsh habitat development consists of defining elevation, slope, shape and orientation, and size (area and volume). The design must provide for placement of the dredged material within the desired limits and required elevations, allowing for settlement due to consolidation of dredged material and foundation soils. Adequate surface area or detention time must be provided for fine-grained sediments to allow settling of suspended solids in order to meet effluent criteria during construction. Various aspects of substrate design are discussed in items 19 and 62. Procedures are equally applicable to both saltwater and freshwater sites.

a. Elevation Control Requirements. The most critical aspect of a marsh development project is usually attainment of a precisely defined stable elevation. Unconfined substrates, normally developed with coarse-grained dredged material, will not undergo significant settlement due to self-weight consolidation. They may, however, require considerable shaving down to reach an intertidal level (Figure 5-8). However, settlements due to consolidation of compressible foundation soils may occur. Confined substrates are normally developed with fine-grained dredged material, and significant settlements of confined substrates may occur due to self-weight consolidation.. One-time construction of confined substrates presents the most critical requirement of prediction of settlements since the initial placement of dredged material must be such that a final elevation within acceptable limits is achieved (Figure 5-9). Since the substrate surface cannot be raised by later placement of additional material, the design must include predictions of settlement to be expected. In incremental construction, the substrate surface elevation is raised by supplemental placement of dredged material, and an exact prediction of settlement for initial layers is not required. Field experience gained by observation of settlement behavior of the initial dredged material layer may be used to aid in prediction of settlement of subsequent layers.

b. Design. for Sedimentation. Confined substrates composed of fine-grained dredged material must be designed for retention of the solids by gravity sedimentation during the dredging operation. Design for sedimentation is directly affected by size of the containment (area and volume), inflow rate (a function of the dredge size), operational conditions, physical properties of the sediment, and salinity of the dredging environment. Design procedures are available that provide for determination of the respective surface area or detention time required to accommodate continuous dredged material placement. Factors influencing hydraulic efficiency of the substrate containment must also be evaluated to include effects of short-circuiting, ponding depth, weir placement, and shape of the containment. If the substrate containment does not provide for adequate sedimentation within the project constraints, it may be possible to increase the substrate containment size, decrease the disposal rate by using a smaller dredge, or increase settling time by using intermittent operations.

c. Weir Design. Retention structures used for confined substrates must provide a means to release carrier water from the disposal site. This is best

Figure 5-8. Heavy equipment was required to shave down sandy dredged material deposits to intertidal levels at Bolivar Peninsula, Texas, and at other man-made wetland sites

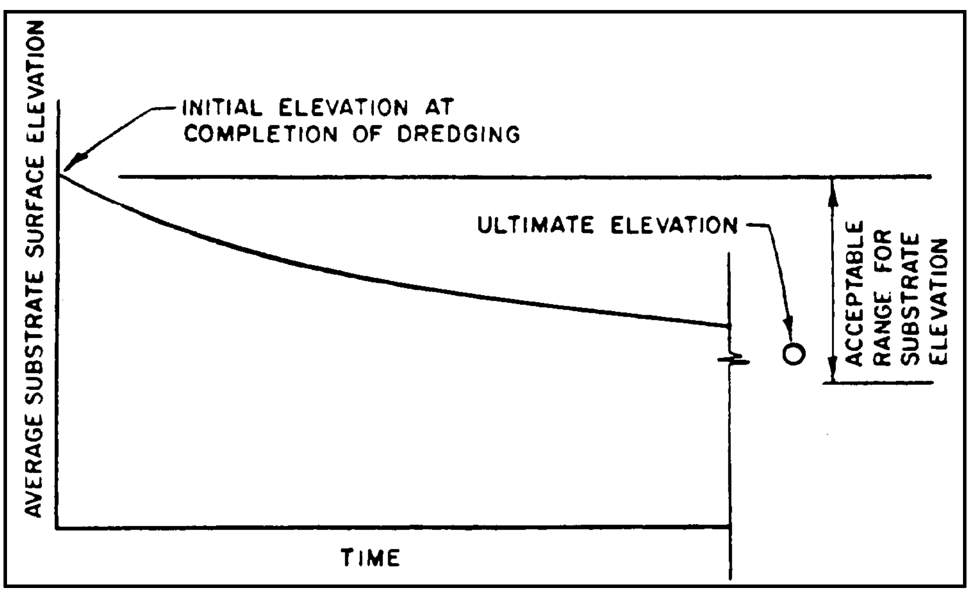


Figure 5-9. Dredged material substrate surface elevations versus time

accomplished by placing a weir structure within the substrate containment. The weir structure must be designed to provide the capability of selective withdrawal of the clarified upper layer of ponded water within the containment without excessive resuspension and withdrawal of the settled solids. Weir design is based on the assumption that sufficient surface area or detention time has been provided for sedimentation and that short-circuiting is not excessive, Weir design procedures are described in Walski and Schroeder (item 82).

d. Requirements for Retention and Protection. Site hydraulics and sediment properties determine the need for retention and protective structures at marsh development sites. These sites may require structural protection from erosion caused by currents, waves, or tidal action. A retaining structure may also be required to retain the dredged material until it consolidates and to control the migration of suspended fines. The first step in the selection of a retention or protective structure is to validate the requirement for such a structure. Particular concern should be given to the effects of any proposed structure on current or wave patterns. Structures which may constrict water flow and increase local current velocities or reflect wave energy may increase erosion. Much of the engineering discussion in this part is detailed in item 17. The relationships between erosion, transportation, and deposition velocities and the sediment grain size are summarized in Figure 5-10. Values are based on velocities measured 6 inches above the bottom of a sediment.

e. Structure Selection Considerations. Considerations in containment structure selection include the dredged material to be retained or protected, maximum height of dredged material above firm bottom, required degree of protection from waves and currents, permanence of the structure, foundation conditions at the site, and availability of structure material. These considerations will determine feasibility of a structure in relation to the project goal, the likelihood that the structure can be maintained over its useful life, and the structure’s total cost. These factors are site-critical and require engineering site data. Several retention and protective structure types are considered technically feasible for use in marsh habitat development and are illustrated in Figure 5-11. Two types of structures are likely to be used in habitat development projects: sand dikes and fabric bags.

f. Design Considerations.

(1) Final elevation of the substrate must be considered in the site design. The first step is to establish the desired elevation of the proposed marsh. Anticipated foundation and fill consolidation to obtain maximum fill level, maximum ponding level, and theoretical maximum dike height of structure include any additional freeboard that may be necessary to prevent overtopping. Allowances for retention structure settlement must also be considered. In the design of containment structures, all the water and earth pressure forces acting on the structure must be considered, as well as any surcharge that is anticipated during construction or in later use. New substrate which requires

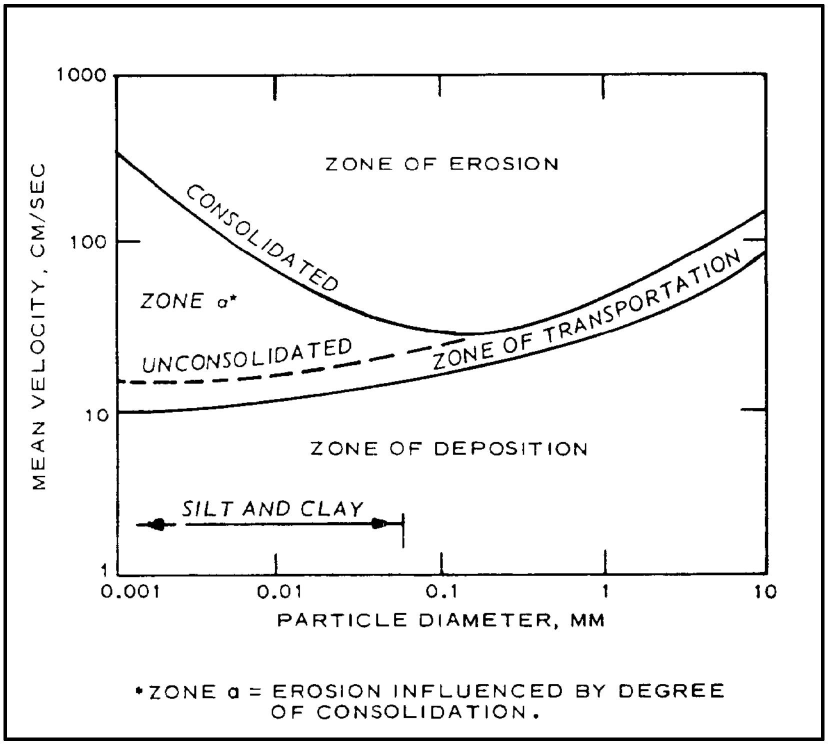


Figure 5-10. Erosion-deposition criteria for different grain sizes

a retaining structure generally will be composed of soft clays and silts, which remain in a slurry state for a significant period after placement. A fluid pressure loading may be exerted on the retaining structure until the substrate begins to consolidate and develop shear strength.

(2) Wind wave characteristics such as height, period, direction, and the probability of occurrence can be found using locally collected data and hindcasting methods. At sites where wind waves appear to be a major consideration, early recognition of that fact may permit relocation or shifting of the site to reduce the open-water fetch in the predominant wind direction, thus limiting the maximum wind-generated wave. In shallow back bays and estuaries, water depth will frequently limit the growth of wind waves (item 17).

(3) Ship-generated waves may also be a major cause of erosion along the edges of marshes. Wave measurements properly timed to ship traffic at the dike site will allow establishment of a design value. Erosion and scour cause the removal of soil particles by water action above and below normal water surfaces; they can cause structural failure and must be guarded against by properly designed protective structures. The erosive ability of water waves

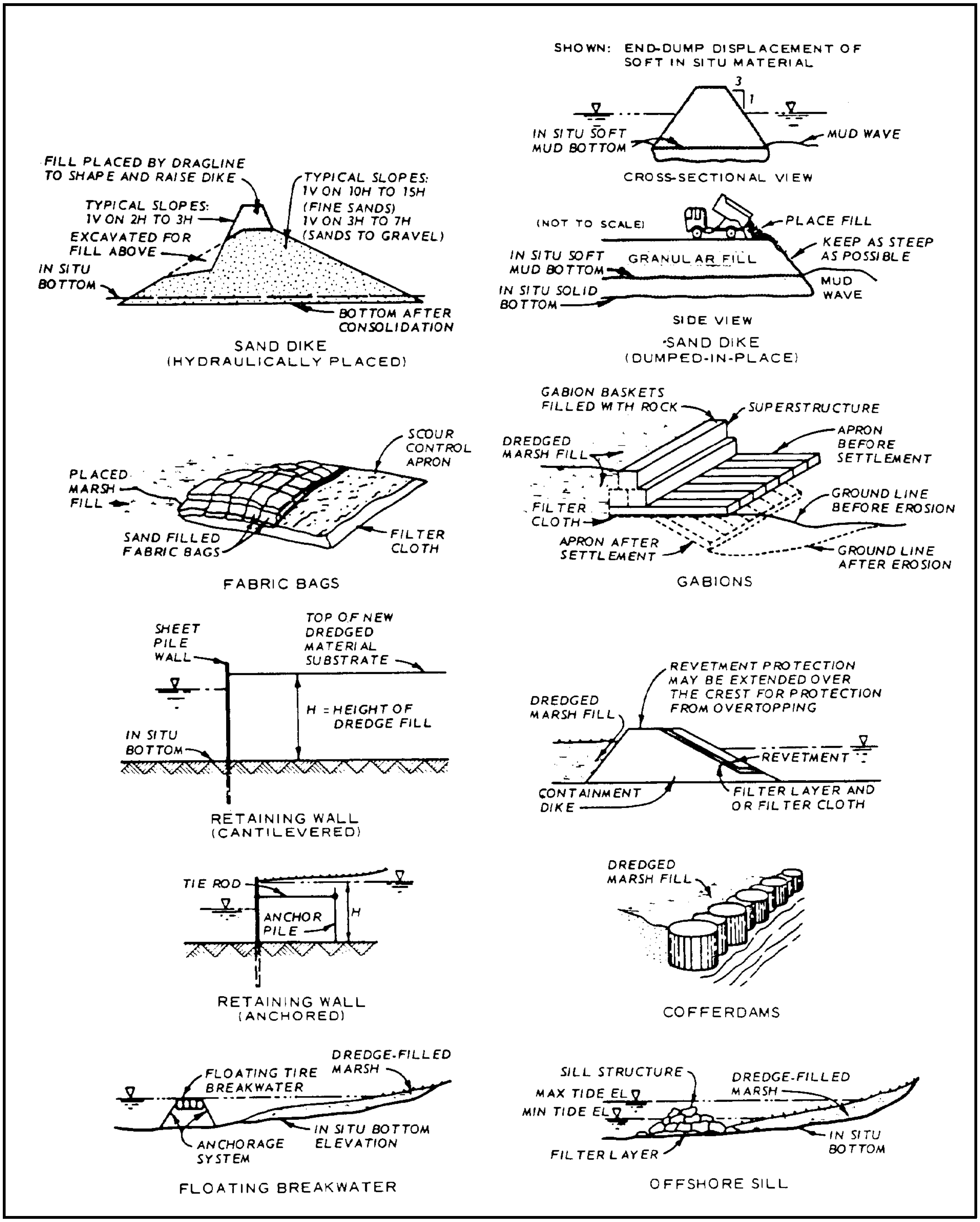


Figure 5-11. Retention and protective structures (item 17)

and currents at a potential disposal site must be considered in the selection and design of a retaining structure and its foundation. Erosion can be minimized by proper location and orientation of the retention/protective structure. Locating the site in a low energy environment is the ideal solution, and a must in many areas. Flattening the outer slopes of the fill or dike will reduce turbulence and scour. Streamlining the upstream face of the fill will also lessen erosion. Vegetation may be used to stabilize the dike and reduce erosion. Protection of inner and outer surfaces by the use of filter cloth, revetment, or antiscour blankets of rubble may be required in higher energy situations. Protection created by breakwaters or floating wave attenuating devices is also possible but may not be economically feasible (item 17).

(4) In riverine environments, an important consideration in determining water velocity must be the effect the fill placement will have on altering the flow conditions. When the fill decreases the cross-sectional area of a channel, there will be resulting increases in flow velocities and/or water surface elevations. These should be estimated and used to evaluate the erosion and scour potential. Foundation stability, stress, settlement, and seepage forces and piping are also important considerations in site design (items 17 and 62) (Figure 5-12).

g. Construction Considerations for Retention/Protective Structures. Characteristics of the site will determine which construction techniques are feasible and greatly influence construction costs. Among the location factors that influence costs are: equipment accessibility, wave and current conditions, tidal range, water depth, bottom conditions, and distance from the dredging site (item 17). Construction techniques and control of these structures are discussed at length in items 17 and 62.

h. Weir Structures. Weir structures are required for release of water during and after the filling operations and should be considered an integral part of the retention/protective structure. Weirs should be well-anchored and collared. Two basic types of weirs are the drop inlet and the box. The drop inlet weir is most commonly used in CE confined disposal operations. The structure consists of a half-cylinder corrugated metal pipe riser equipped with a gate of several stop-logs or flashboards that serve as a variable height weir. They can be added or removed as necessary to control flow into and out of the containment area. A discharge pipe leads from the base of the riser through the dike to the exterior. The box weir consists of an open cut through the entire dike section. The cut is usually lined with timber but could be lined with concrete or steel. Box sluices also use stop-logs for controlling drainage. Box sluices are not often employed. However, box sluices are capable of rapidly discharging large volumes of water. This feature could prove advantageous in marsh establishment since natural water level fluctuations throughout the containment area may be necessary during construction and are essential to the natural operation of the new marsh. Additional information regarding weir design, construction, and operation can be found in items 30, 62, and 82.

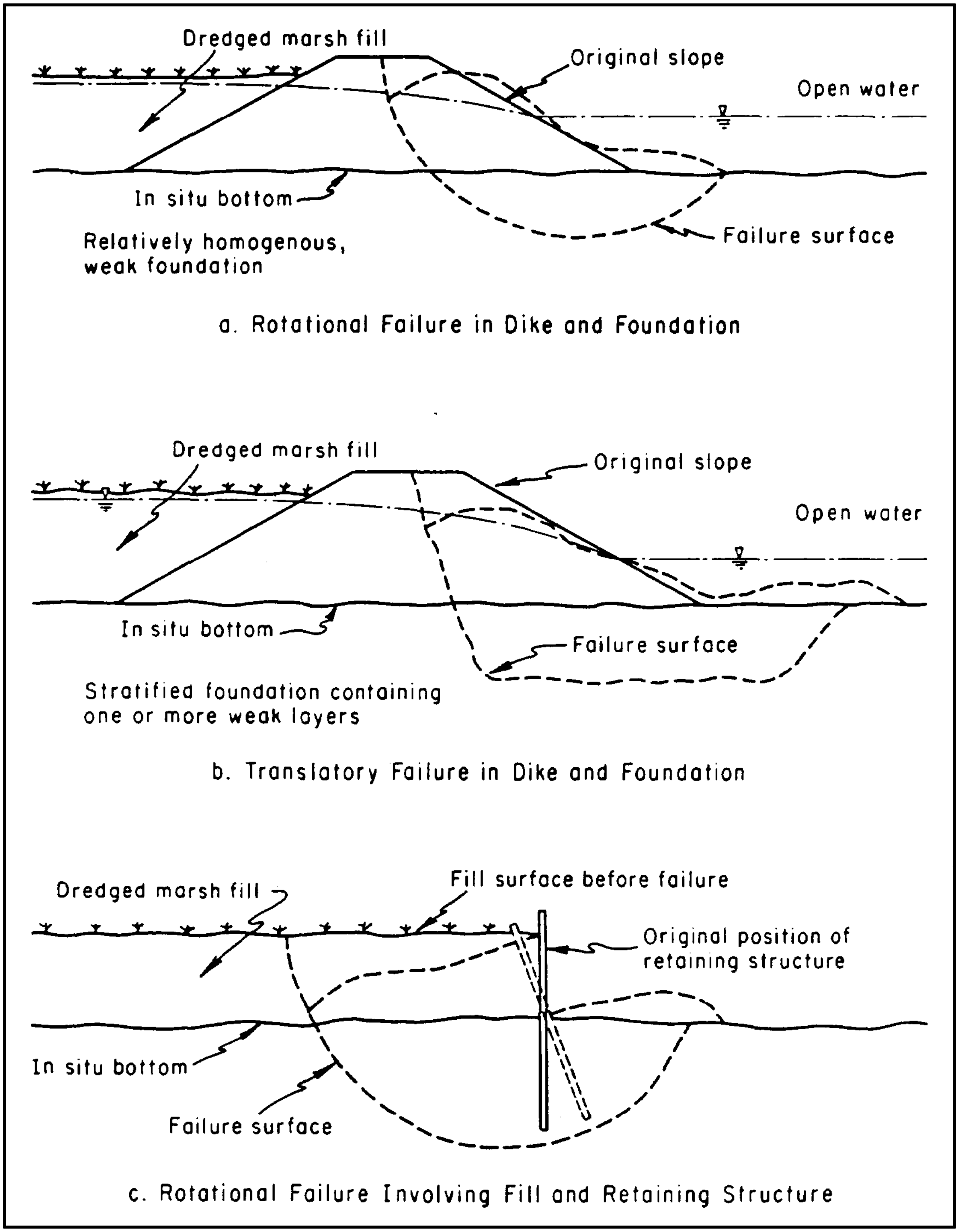


Figure 5-12. Examples of typical slope failures (item 17)

i. Dredged Material Placement Operations. Material may be placed within the disposal site using either hydraulic or mechanical methods. The hydraulic pipeline dredge is by far the most commonly used method and will provide the major source of material to be used for marsh establishment. Pipeline length can be extended to several miles with the addition of intermediate booster pumps, but at a substantial additional cost (item 19). Hydraulic transport of material assumes additional prominence when one considers that the newer concepts for dredged material handling systems involving direct pumpout of bucket-loaded scows usually involve final disposition via pipeline. The pipeline dredge can dispose of material in shallow-water areas through the use of shore lines or shallow-draft floating pipelines. Detailed information on obtaining selected dredged material for dike construction, operations for placement of the material, movement of pipelines in shallow-water areas and on the shoreline, energy dissipators, operational guidelines, and the influence of dredged material placement on structures is presented in item 19.

j. Management Activities for Confined Substrate Placement. Placement of dredged material within a confined area is identical with placement in any other containment area. Certain management activities are therefore necessary to ensure that suspended solids are retained within the area and that effluent quality is maintained (items 4 and 62). The management of surface water can be accomplished by controlling the elevation of the outlet weir(s) throughout the operation to regulate the depth of water ponded within the containment area. Proper management of surface water is required to ensure containment area efficiency and can provide a means for access by boat or barge to the containment area interior. At the beginning of the placement operation, the outlet weir is set at a predetermined elevation that will ensure that the ponded water will be deep enough for settling as the containment area is being filled. As the operation begins, slurry is pumped into the area; no effluent is released until the water level reaches the weir crest elevation. Effluent is then released from the area at about the same rate as slurry is pumped into the area. Thereafter, the ponding depth decreases as the thickness of the dredged material deposit increases. After completion of the placement operation and of the activities requiring ponded water, the water is allowed to fluctuate with the tides through the existing weir structure. Use of the ponded water for floating the pipeline within the containment area can be of benefit to general containment area management by greatly facilitating the movement of the inlet point without disruption of the dredging operation. The floating inlet allows selective placement of coarse-grained material behind the retention structure or at desired mounding locations within the substrate. Once the substrate has achieved the desired degree of stability and after careful consideration of the erosion potential of such an action, the weirs or retention structure may be breached to allow natural water circulation throughout the substrate area.

5-5. Wooded Wetland Habitats. In contrast to marsh development, almost no development of wet woodlands on dredged material has been researched or field implemented. Item 41 developed guidelines and drew restoration plans for bottomland hardwood sites and floodplain islands. Guidelines are not available for cypress/tupelo swamps nor for northern woody bogs, types of wooded wetlands commonly encountered by the CE. Since dredging operations and disposal sites are generally carefully steered away from wooded wetlands and wooded wetland habitat development has been very infrequent, this EM will not address these types of habitats.

CHAPTER 6

UPLAND HABITATS

6-1. General. Upland habitats encompass a variety of terrestrial communities ranging from bare soil to dense forest. In the broadest interpretation, upland habitat occurs on all but the most disturbed disposal sites. For example, a gravelly and bare disposal site may provide nest sites for killdeer or tern species; weedy growth may provide cover for raccoons or a food source for seed-eating birds; and water collected in desiccation cracks may provide breeding habitat for mosquitoes. The essential fact is that man-made habitats will develop regardless of their management; however, the application of sound management techniques will greatly improve the quality of those habitats (item 72)

6-2. Upland Habitat Development Considerations. Upland habitat development has potential at hundreds of disposal sites throughout the United States. Its implementation is largely a matter of the application of well-established agricultural and wildlife management techniques.

a. Advantages. Upland habitat development as a disposal alternative has several distinct advantages:

(1) Adaptability.

(2) Improved public acceptance.

(3) Creation of biologically desirable habitats.

(4) Elimination of problem areas.

(5) Low-cost enhancement or mitigation.

(6) Compatibility with subsequent disposal.

The principles and applications of this alternative are adaptable to virtually any upland disposal situation. Regardless of the condition or location of a disposal area, considerable potential exists to convert it into a more productive habitat. Small sites in densely populated areas may be keyed to small animals adapted to urban life, such as seed-eating birds and squirrels. Larger tracts may be managed for a variety of wildlife including waterfowl, game mammals, and rare or endangered species. The knowledge that a site will ultimately be developed into a useful area, be it a residential area, a park, or wildlife habitat, improves public acceptance. Many idle and undeveloped disposal areas that are now sources of local irritation or neglect would directly benefit from upland development, and such development may well result in more ready acceptance of future disposal projects. Upland habitat development will usually add little to the cost of disposal operations. Standard procedures may involve liming, fertilizing, seeding, and mowing. A typical level of effort would be similar to that applied for erosion control at most construction sites and considerably less than that encountered in levee maintenance. Unless the target habitat is forest, this type of habitat will generally be compatible with subsequent disposal operations. In most situations, a desirable vegetative cover can be produced in one growing season. Subsequent disposal would simply require recovery of the lost habitat. Indeed, the maintenance of a particular vegetation stage may require periodic disposal to retard or set back succession (item 73).

b. Disadvantages. The disadvantages of upland habitat development are potential public opposition to subsequent disposal and possible necessity of long-term management. The development of a biologically productive area at a given site may discourage subsequent disposal or modification of land use at that site. This problem could be avoided by the clear identification of future plans prior to habitat development, or by the establishment and maintenance of biological communities recognized as being most productive in the earlier stages of succession. In the latter case, subsequent disposal may be a necessary management tool. Some habitat types will require management. For example, if annual plants such as corn are selected for establishment, then yearly planting will be necessary. If the intent is to maintain a grassland or open-field habitat, it may be necessary to mow the area every 2 to 5 years to retard woody vegetation. In most cases, it will be possible to establish very low maintenance habitats, but if the intent is to establish and perpetuate a given habitat type, long-term management will be essential and may be expensive.

6-3. Guidelines for Upland Development.

a. Upland Habitat Needs and Assessments. Those upland habitats in limited supply should be identified and the opportunity for additional habitat assessed. Public attitudes are of particular consequence in the implementation of this alternative, and public opinion should be actively sought. Site selection should be made with a particular target habitat in mind as the importance of other habitats will be greatly influenced by the needs and attributes of the surrounding area. The chemical and physical properties and the relative quantities of different types of dredged material should be evaluated to determine the characteristics of the soil to be used in the habitat development. Several remedial treatments are possible. For example, it may be possible to improve the agricultural characteristics of the surface layer by top dressing the site with material selected for its agronomic characteristics. It may also be possible to bury a problem soil by capping it with a layer of clean material.

b. Planning and Design.

(1) Assuming that upland habitat development has been selected as a disposal alternative or as an enhancement measure, habitat planning and design guidelines are indicated in Figure 6-1. The criteria discussed under site

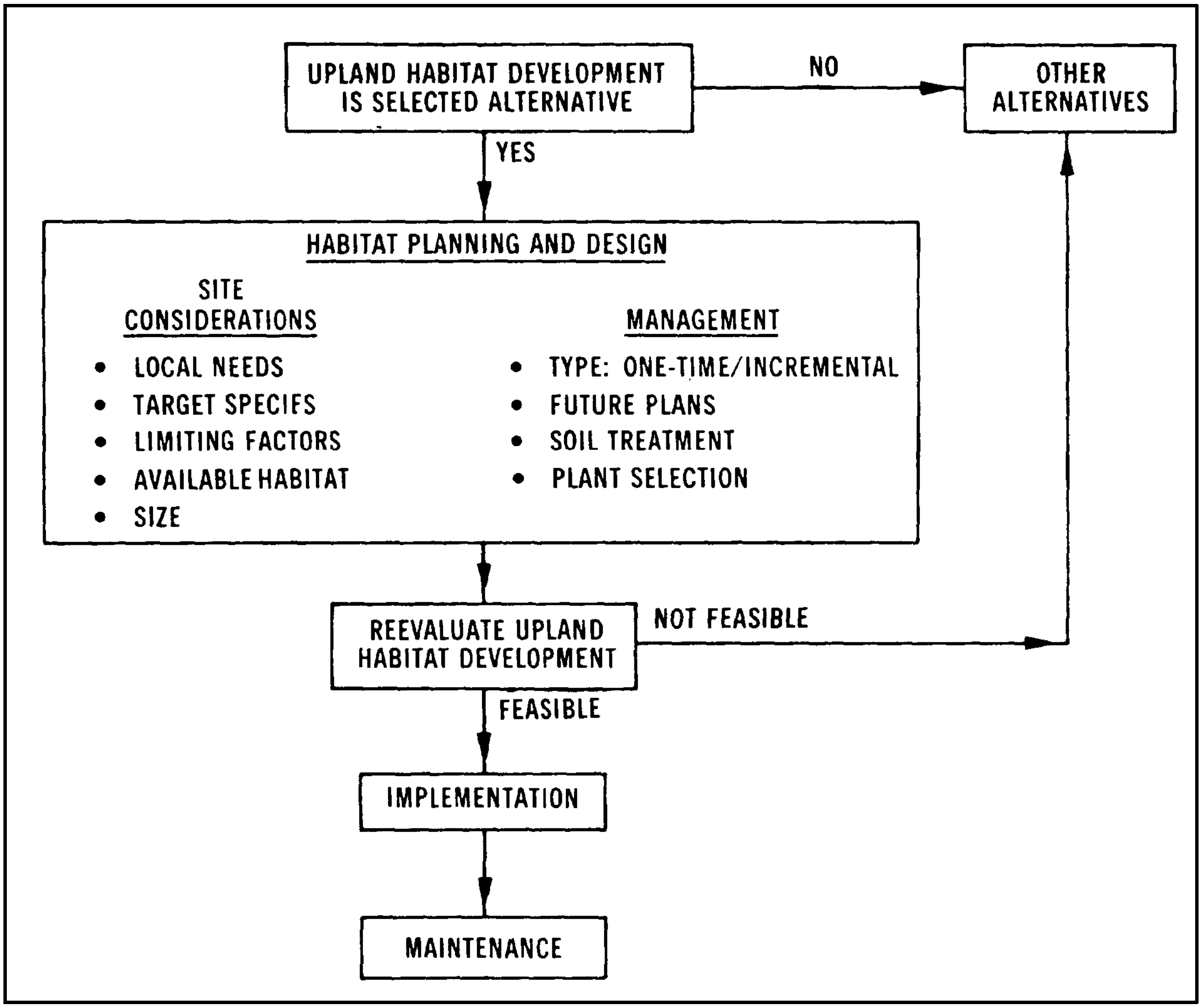


Figure 6-1. Procedural guidelines for selection of upland habitat development

considerations are applicable regardless of whether the site is a new or previously used disposal area. Local needs and thereby target wildlife species will be determined primarily by the desires of state wildlife agencies and those of the public. These needs are likely to reflect local perception of the value of wildlife. If the area has a strong hunting tradition, the emphasis may be on game animals. If there is strong agency concern for an endangered species, that may be the emphasis. In many cases, a target species per se will not be identified. Rather, a grouping such as "songbirds" or "small game" will be designated. The list of target species must be evaluated in light of the available habitat surrounding the site and the size of the disposal site. The size of a disposal area will seldom be large enough to exert a significant impact on regional animal populations if it only duplicates existing habitat types. Therefore, the success of the site will usually be determined by its ability to enhance surrounding habitats or remedy limiting environmental factors.

(2) Basic management decisions will depend on the type of disposal and future plans at the site. If one-time disposal with periodic maintenance is planned, the management plan may be quite flexible. One-time disposal without management indicates the need to establish a plant community that is relatively self-sustaining. If periodic disposal is planned, plant communities that are rapidly functional are advised. Properly planned, periodic disposal could be considered a wildlife management option used to control succession or diversify the habitat and avoid confrontation regarding subsequent activities. Future plans for any habitat development site should be well documented and understood by interested agencies and the public prior to implementation.

(3) Soil treatment and plant selection are closely related and can proceed after determination of the type of disposal, identification of the characteristics of the dredged material, and determination of target species have been completed. Soil treatment may include a variety of activities such as burying problem materials, dewatering, mixing materials to obtain improved soil characteristics, leaching, fertilization, and liming (Figure 6-2). Plant selection will be dictated by soil conditions and habitat preferences. In many situations it will be possible to identify highly desirable natural plant communities near the disposal area. Development of site conditions (soil, elevation, diversity) on dredged material that are similar to those of desirable plant communities will encourage natural invasion and natural development of similar communities. When this is possible, a considerable savings in planting and maintenance costs may be realized.

c. Reevaluation and Implementation. If, upon reevaluation, the upland habitat development alternative remains feasible, the project may be implemented and subsequently maintained. Implementation will be highly site specific but should present few difficulties beyond the problems typically encountered in contracting new or unusual work. Advice from local wildlife biologists and soil scientists may prove invaluable in this stage.

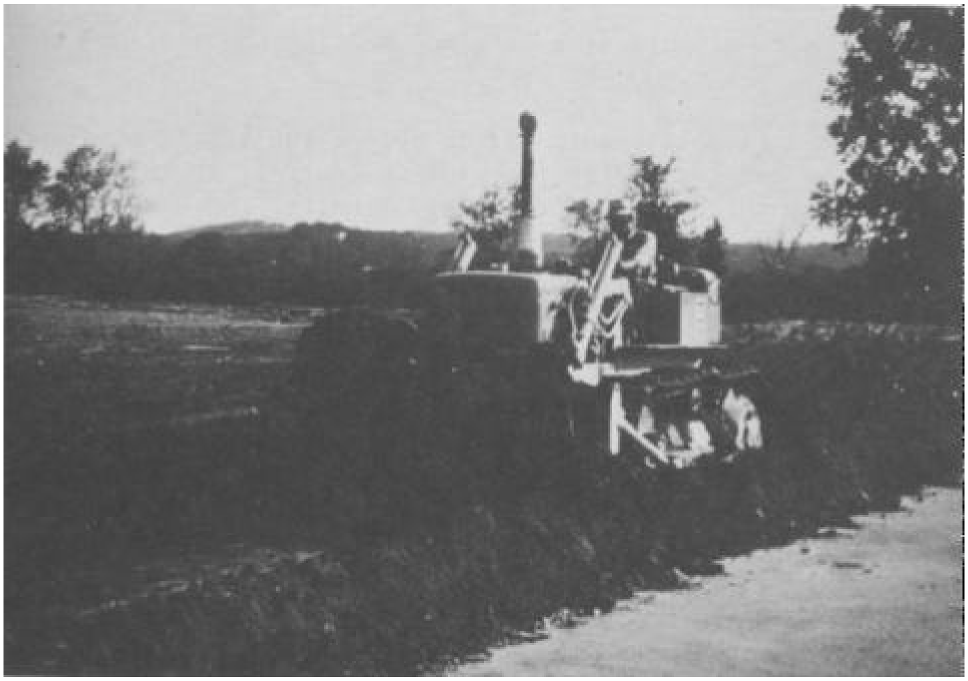


Figure 6-2. Mixing layers of silty and sandy dredged material at Nott Island upland site, Connecticut River, Connecticut

6-4. Upland Site Development.

a. Site selection. Two types of upland habitat development sites have potential beneficial use: older, existing sites where habitat development and enhancement occurred, and planned sites where upland habitat development is part of the project goal. In both cases, several factors determine selection of the best possible site: availability, disposal need capacity, proximity to dredging area, physical and engineering characteristics, environmental and social acceptability, tidal and current considerations, and habitat development feasibility.

b. Site characterization. After the upland disposal site has been selected for development, field and laboratory investigations of the site and related areas should be initiated. If the site is an older disposal area to be reclaimed, it and the surrounding area should be evaluated physically and biologically to assess its potential for habitat development and determine necessary action. If dredging and disposal operations are involved, it will be necessary to add information related to the site’s capacity, need for and design of a protective or retention structure, and construction details. This information should be collected in conjunction with characterization of the sediments to be dredged. Physical, biological, socioeconomic, and engineering tests should be made to determine site suitability (items 32 and 62) and acceptance. Target wildlife species should be identified, and other potential upland objectives such as site stability and multiple habitat use should be considered.

c. Vegetation establishment. Since upland habitat is developed primarily for wildlife and less often for erosion control, it is important to key in on target species that will use the disposal site. An excellent example is the Nott Island site in the Connecticut River, Connecticut, where a mixture of grasses and legumes was planted as a nesting and grazing meadow for waterfowl, deer, and small mammals (Figure 6-3). Although an animal's habitat consists of a wide variety of components, vegetation is by far the most important. Vegetation growth form, height, density, placement, diversity or uniformity, seasonal changes, biomass, and hardiness strongly influence species composition, abundance, and well-being of wildlife. Secondary objectives of recreation, aesthetics, erosion control, and soil quality also depend in part on

Figure 6-3. Nott Island habitat development site, showing the planted nesting and grazing meadow after 5 years of development

vegetation. These relationships make it necessary to begin consideration of the ultimate vegetation of the site early in the planning process. Three methods of upland vegetation establishment exist: allowing natural plant invasion and establishment, planting selected species, and combining natural establishment with planned propagation.

(1) Natural invasion and establishment. The ability of propagules to reach the upland site is the most important factor in describing the potential for natural colonization on dredged material. This ability increases as the distance from a propagule source decreases and as the size of the site and ease with which the propagule can be transported increase. Propagules may be transported over a distance by wind or water; by attaching themselves to an animal's fur, feathers, or feet; by being ingested and excreted by an animal; or by attaching to a human. Secondary factors in the potential for natural colonization include physical and biological features of the site itself. Plants growing and reproducing on the site will reestablish after deposition of dredged material if the deposit was not too thick and if new substrate conditions are not prohibitive. Plants growing and reproducing near the area will establish only if seeds blow or are carried onto the site, if rhizomes or other vegetative reproduction forms extend onto the site, and if the new substrate conditions are not prohibitive.

(2) Planting selected species. Standard practices in agronomy are usually sufficient to handle plant propagation on upland sites. With appropriate planning and management, any site can be vegetated within a few years and most sites within a year. Planting upland sites ensures that desirable vegetation grows there, that substrates stabilize rapidly, and that aesthetic appearances of disposal sites improve faster. The chief disadvantage over natural invasion is the cost involved with site preparation and plant propagation and establishment.

(3) Combining natural establishment and planting. A combination of the two methods of vegetation establishment may be beneficial. Allow invasion to stabilize the substrate and start modifying the sediments, then plant a different type of vegetation when the season or timing or soil conditions are more suitable. The reverse also is possible: to get immediate benefits of selected plantings, plant the site, then allow the site to proceed in natural successional stages. Also, use subsequent deposits of dredged material to set back vegetation succession to a more desirable stage.

d. Selecting Plant Species and Propagule Type.

(1) Selecting plant species.

(a) If the site is to be planted, advance consideration must be given to the plant species that will create the desired habitat for the target wildlife species. An initial selection of species should be made during the planning phase, even though once the site is established, alternate species may prove to be more acceptable and be substituted for those originally selected (item 32). Numerous species are suitable for planting upland dredged material sites (item 39). Item 13 identifies, by state, 250 species or species groups that are of benefit to wildlife and adapted to grow on dredged material and presents species growth characteristics, habitat requirements, ranges, and tolerances of 100 of these. Item 45 identifies 50 species generally useful for dewatering and decontaminating dredged material. Item 54 gives growth characteristics of many tree and shrub species suitable for confined upland disposal areas. Items 12, 39, and 73 summarize data on plants known to grow on dredged material sites.

(b) Other species of more local character are available, and many species with unknown tolerances and adaptability may prove useful after field testing. Local soil conservation service personnel and agronomists will be able to provide updated information on species and new varieties. Selection of species or species mixtures to be planted at a particular disposal site must include consideration of project goals, climate, substrate characteristics, plant species characteristics, plant species availability, ease of propagation, management requirements, and costs. Certain species mixtures are commonly planted, such as a clover and a grass species, to take advantage of the different properties of each. Occasionally the mixture will not be successful because of interactions among the species and because the soil is too acidic, infertile, or compacted.

(2) Selecting propagule type. Items 32 and 39 give the best propagule types for selected plant species, based on criteria of availability and cost, ease of collection and handling, ease of storage, ease of planting, occurrence of disease, and need for rapid vegetation establishment. In general, seeds are cheaper and easier to work with than vegetative propagules such as cuttings, sprigs, or seeding in upland habitats. However, some plant species and planting situations require vegetative propagules, e.g., to rapidly stabilize the exterior of a sand dike.

(3) Handling plant material. If commercial seed sources are not available, collection and storage of wild seeds should follow the guidelines in item 32. Some desirable species are available as transplants (potted, balled and burlapped, or bare-rooted nursery stock). However, many upland plants that are desirable as long-term cover and food sources, such as trees and shrubs, are not commercially available.

e. Preparing and Planting the Site.

(1) Substrate modification. Once the dredged material has been placed and dewatered sufficiently to allow equipment access, it can be modified as necessary. Modifications will usually be directed toward preparing the substrate for vegetation establishment, and will depend on the condition of the substrate and the exact design of the project. In upland habitats, these activities are largely agronomic.

(a) Mechanical modification. The site may require grading to change the topography that resulted from disposal, e.g., to make the slope uniform by removing depressions or mounds, increase relief by making depressions or mounds or altering the slope, make islands, or raise low spots. Variation in texture of the sediments results either intentionally by disposal of more than one type of material or naturally through hydraulic sorting during disposal. This variation may need to be reduced to a more uniform soil for ease of seedbed preparation. This can be done by repeated passes with a blade or deep plowing followed by disking. If possible, grading should be done at the time of year when precipitation is lowest to reduce erosion of the bare soil. Seedbed preparation includes plowing or disking one or more times to break up clumps and aerate the soil, fill or cover desiccation cracks, even out moisture content, destroy unwanted vegetation that may have invaded, turn under green manure, incorporate soil amendments, and in general improve the quality of the substrate. Preparation is best done several months prior to planting and again just before planting, if labor and equipment are available. Success of the site may depend especially on this process.

(b) Chemical modification. Prior to final mechanical seedbed preparation (preferably several weeks to months ahead), the substrate at the site should be sampled and the soils analyzed chemically in the same fashion as for site characterization. Their properties may have been altered by dredging and dewatering from what they were in the initial tests. Some of the common problems that may be found include high salinity levels, soil acidity or alkalinity, or lack of one or more of the essential plant nutrients at levels sufficient to support good plant growth. These can be corrected with soil amendments, leaching, or other techniques (item 32).

(c) Biological modification. Biological modification of the substrate may also aid in the success of the project. This could include such things as removal of existing and competitive vegetation by cutting, short-lived herbicide application, or cultivation; growth of a preliminary green fertilizer crop; or addition of farmyard manure, sewage sludge, etc., on light-textured sands to improve their nutrient- and moisture-holding capacity. If legumes are to be grown on the site, the seed should be inoculated with the proper strain of Rhizombium bacterium to improve chances of fixing adequate amounts of atmospheric nitrogen.

(2) Timing. Timing of all factors related to plant establishment is an important consideration in habitat development. Adequate planning will have allowed lead time to locate, obtain, and prepare sufficient amounts of viable seeds or vegetative propagules, including any period of seed dormancy. Timing of planting will strongly influence plant success. For example, seeding warm weather annuals before the last cool period in spring will result in heavy crop damage, and seeding the same seeds in midsummer will result in heat and drought stress during sprouting. Seeding of cold weather species too early in the autumn will result in sporadic germination, increased chances of insect infestations such as army worms, and heat and drought stress. Optimum seeding times vary with climatic regions and photoperiods, and local agronomic authorities should be consulted before planting. Refer to items 32 and 39 for species-specific details on timing.

(3) Planting.

(a) Temperature. Vegetative propagules may be planted any time the ground is not frozen and any time the day temperatures average less than 68°F.

In general, March to May is best for warm weather plants and September to November for cold weather plants over most of the United States. In the Deep South, transplanting is usually done successfully from October through May, with June through September being too hot. Dormant propagules may be more readily transplanted in winter months. Propagules held in storage inside a nursery or greenhouse should not be planted until temperatures at the field site are at least as warm as the storage area, to lessen shock. Propagules held in a shady area should be gradually acclimated to sunny conditions if the site is in the sun, to prevent blistering and death of leaves and plant shock. General planting methods are given in Items 32 and 39; specific recommendations for local conditions can be obtained from the Soil Conservation Service or county extension service agents.

(b) Methods. Methods of planting vary with the propagule type. Seeds should be sowed in a well-prepared seedbed that has been plowed and/or disked to a depth of at least 6 inches. It is important to consider planting techniques and equipment, seeding rates and depths, and seed and soil treatments when using seed propagules. For transplants, types of propagules, planting techniques and equipment, transplant spacings, timing of planting, plant growth habits, and long-range project goals are all important factors in determining site success (item 32).

6-5. <u>Engineering Design of Upland Sites</u>. Guidelines for substrate design and sediment protection and retention apply to both a new disposal area or one that may already have a retention structure and some material placed. Design should be based on information gathered during the site description, on results of field and laboratory tests, and on the requirements for the planned habitat development. The majority of the information in this section was compiled from items 17, 32, and 62. Dredged material may be placed by either hydraulic or mechanical methods. The hydraulic pipeline dredge is the most commonly used and will continue to be the major source of dredged material to be used for upland habitat development. Hydraulic transport of material assumes additional prominence when one considers that the newer concepts for dredged material handling systems, involving direct pumpout of hopper dredges, temporary containment basins, or bucket-loaded scows, usually involve final disposition by pipeline. The pipeline dredge can dispose of material in upland areas through the use of shore lines or shallow-draft floating pipelines.

a. Substrate Design.

(1) Elevation. Substrate design for upland habitat development includes determination of site elevations, slope, orientation, configuration, and size (area and volume). The design must provide for placement of dredged material to a stable elevation within the desired elevation limits, allowing for settlement due to consolidation of both the sediments and foundation material. For fine-grained sediments, the substrate must be designed to provide adequate surface area and retention time for sedimentation of suspended solids. Procedures for substrate design generally follow those established by

items 56 and 62 for the design of conventional containment areas. The determination of substrate elevation is governed by two limitations: the project requires placement of a given channel sediment volume, and the size to handle this volume within elevation limits must be determined; or the project requires a substrate to be constructed within given size limits, and the volume of channel sediment to construct this substrate must be determined. In either of these cases, a correlation between in situ sediment volumes and volumes occupied by the dredged material must be determined. The first step is to calculate void ratios by determining water content of samples of the sediments to be dredged. The second is to compute the void ratio of the dredged material after dredging and deposition (items 56 and 62).

(2) Sedimentation of solids. Confined disposal areas with primarily fine-grained dredged material should be designed to retain solids by gravity sedimentation during the dredging operation. Solids retention is directly affected by the size of the confinement area (particularly length and depth), inflow rate (dependent on dredge size and operation), physical properties of the sediment, and salinity of the water and sediments. Items 56 and 62 detailed separate design procedures for determining sediment retention time requirements for fresh and saline sediments with continuous disposal. In addition, these procedures include factors influencing efficiency of the substrate containment, effects of short-circuiting, ponding depth, weir placement, and shapes of containment. In the event that substrate containment does not provide an adequate gravity sedimentation basin, then one of the following alternatives must be exercised:

(a) The size of the site must be increased.

(b) A smaller dredge must be used.

(c) Intermittent dredging and/or disposal operations must be initiated.

(3) Weir design. Retention structures used to confine dredged material must provide a means of releasing carrier water back into the waterway, which is best accomplished by placing a weir within the containment area. Effluent quality can be strongly affected by the design and operation of the discharge weir, with the weir length and ponding depth having the greatest control on this quality. Item 82 developed a design procedure for defining weir length and ponding depth to minimize the discharge of solid particles into the waterway.

(4) Dredged material settlement. Settlement will occur following completion of the dredging operation because of the self-weight consolidation of the dredged material layer and/or the consolidation of compressible foundation soils. Estimated settlements may be determined by procedures presented by item 62. Once loading conditions are determined, ultimate settlements that occur after the completion of 100-percent primary consolidation can be estimated from laboratory consolidation data. This settlement is not as critical as for wetland habitats, but is important because of the ponding effect it

causes. Time rates of consolidation for both the dredged material and foundation soils are required to determine the relationship between the desired final substrate elevation and time. If the data from the laboratory tests reveal that settlement will not meet desired elevation requirements, an adjustment to the substrate configuration must be made to raise or lower the initial substrate elevation as required.

b. Substrate Protection and Retention.

(1) Requirements for a structure. Data gathered for the site description should be used to determine if a protective or retention structure will be needed for the upland site. Engineering data collected at a specific site should determine: amount and character of material to be protected or retained, maximum height of dredged material retained above the firm bottom, degree of protection from waves and currents required, duration of the structure, foundation conditions at the site, and availability of construction material. All habitat development sites may require a structure for protection of the perimeter from erosion caused by currents, waves, or tidal action. Particular concern should be given to the effects of any proposed structure on existing current or wave patterns. A structure positioned so that it constricts the water flow will increase local current velocities or reflect wave energies, and thus may encourage erosion. All habitat development sites may require structures for retention of the dredged material to allow it to consolidate, to control the suspended solids content of the effluent, or to protect surrounding habitat or adjacent structures. Site hydraulics, the properties of the sediment to be dredged, the time over which disposal will occur, and the existing site characteristics are closely interrelated in determining the need for such structures.

(2) Selection of structure. The protective or retention structure should meet four conditions:

(a) Suitability to the project goals of dredged material disposal and habitat development.

(b) Practicality and ease of construction.

(c) Ease of maintenance.

(d) Reasonableness of cost.

Item 17 evaluates several protective and retention structures considered technically feasible for use in terrestrial habitat development and presents information on structure selection, applicability to specific site conditions, and conceptual procedures for design and construction. The most feasible structures are often dikes constructed from filled fabric bags or from sand in moderate to low wave-energies in temperate climates (item 17). The term "fabric bag" covers products from several producers of sacklike containers that can be filled with sand, sand-cement, or concrete and used as building blocks for breakwaters, groins, revetments, or containment dikes. Rock and rubble from new work dredging can also be used.

(3) Design of structure. EM 1110-2-1902 and EM 1110-2-2300 provide proven methods for design and construction of earth- and rock-filled structures. Those procedures should be used to supplement engineering considerations of elevation requirements and earth and water pressure forces. Internal structures may be advisable. Cross and spur dikes are used to control circulation within a disposal area, with the cross dike commonly employed to divide large disposal areas into smaller cells, and spur dikes employed to interrupt direct slurry routes between the inlet and outlet. The cross dike is the more significant of the two structures for habitat development purposes, since use of a cross dike allows flexibility in disposal including incremental filling and separation of dredged material by grain size. (See Figure 15-2, Chapter 15, for riprapped structures and cross dikes used at an upland habitat site.)

(4) Construction of structure. Site-specific factors affecting construction techniques are: equipment accessibility, wave and current conditions, tidal range, water depth, bottom conditions, and distance from the dredging site (item 17). The construction material used and method of construction are significant factors. In addition to the fabric bags previously discussed, three basic types of retention structure construction exist: hauled dikes, cast dikes, and hydraulically placed dikes (item 30). Construction techniques for retaining walls, sills, breakwaters, gabions, and other structures are highly site specific and should be determined on a case-by-case basis (item 30).

6-6. Ecological Design of the Upland Sites. Planning for a habitat development site should be based on sound ecological principles and should attempt to make efficient use of available resources in reaching the goal. The two major resources that can be manipulated for habitat development are substrate (in this case, dredged material) and vegetation. All previous aspects of planning should be united in the ecological design of the site for proper placement of dredged material and vegetation.

a. Placement of Dredged Material. Many aspects of the engineering design of an upland disposal site are directly related to the site’s potential biological characteristics. Physical appearance of the site is particularly important, and structures, configuration, size, elevation, topography, timing, and site interaction with surrounding habitats must be considered for ecological integrity of the upland site.

b. Placement of Vegetation. Presence or absence and patterns of vegetation are critical factors in habitat development. Such ecological concepts as structural diversity, community size, species patterns of abundance, and biotic succession are pertinent. Specific concepts that should be applied to upland habitat design are diversity, ecological succession, habitat patterning, and vegetation structure and function.

6-7. Dredging and Disposal Operations.

a. Construction. The first step in construction of an upland habitat development site is to build a protective or retention structure, if called for in the project design, or to modify an existing structure or site (e.g., raise a dike or add drainage). Some site preparation may be necessary, perhaps construction of an access route or removal of vegetation. Access for equipment and pipes should be built to minimize damage, especially to wetlands. Unless the project calls for shallow disposal and recovery of plants present on the site, vegetation to be covered should be mowed or cut to prevent recovery after disposal or to prevent dead branches and shrubs from protruding. Clearing and grading are required along the dike alignment to allow construction.

b. Dredged Material Placement. A significant amount of material rehandling is sometimes required in developing upland habitat because the final distribution of material at the site is important. This handling can be reduced if the initial location and distribution of the coarse- and fine-grained fractions of the dredged material are controlled. One means of control is to take advantage of the differential settling characteristics of the various sized particles in the dredged slurry. Another means is to operate the dredging plant and peripheral equipment in a manner that will produce the desired substrate (item 4). For the majority of disposal operations, the criteria for locating the discharge pipeline in the disposal area have been to maintain an adequate flow distance relative to the weir, keep the discharge end of the pipeline a safe distance away from the interior slope of the dike, and minimize the pumping distance from the dredge. The criteria are directed at preventing short-circuiting or channelization of the flow through the containment area, avoiding scouring damage to dikes, and minimizing pumping costs. Some modifications of these pipe location criteria may be required if advantage is to be taken of particle size differential settling characteristics for habitat development. Coarse-grained material encountered during dredging operations can be taken advantage of with end-of-pipe operations. If the character of the sediment-water slurry being transported is known beforehand or can be determined by monitoring at the dredge or at the end of the pipe, then the coarse material can be diverted by use of a wye connection without interrupting the dredging operations or the dredging sequence. The diverted material can be placed directly in the desired location hydraulically or stockpiled for later use in habitat development. Stockpiling and subsequent rehandling of the material are roughly equivalent to obtaining the material from a source outside the disposal area and involve the use of additional or supplementary equipment.

c. Containment Area Operation. Activities during substrate material placement are aimed at the retention of solids and production of an effluent that will meet criteria for release into the waterway. Operational difficulties, such as channelization of the dredged slurry and insufficient ponding depth, may result in excessive amounts of solids leaving the disposal area through the weir. This is counterproductive and usually violates laws and regulations. Therefore, it is recommended that during and after the disposal operation a well-planned monitoring program be implemented to ensure that suspended solids in the effluent remain within acceptable environmental limits. Suspended solids retention can sometimes be increased by increasing ponding depths through efficient operation of the weir. Concepts of containment area management instituted immediately following the completion of a disposal operation are also important to successful implementation of a habitat project. The most important aspect of dredged material disposal area management was to remove all surface water as fast as possible to enhance surface drying (item 4). This conclusion can be extended to include terrestrial habitat development since extensive site activity must usually wait until the substrate is trafficable. In addition, working the area to a gentle slope toward the effluent point allows efficient drainage of surface water, and evaporative dewatering can be supplemented by transpiration by vegetation.

d. Quality Control. Specifications for all phases of construction should be detailed and clear. Thorough inspection of all operations will ensure that the work is in compliance with plans and specifications for upland habitat development and any mitigation requirements, and will mean fewer post-dredging operations and lower project cost.

CHAPTER 7

ISLAND HABITATS

7-1. General.

a. One hundred years of active dredging operations by the CE, state agencies, and private industry has resulted in the creation, by placement of dredged material, of over 2,000 man-made islands throughout U.S. coastal, Great Lakes, and riverine waterways (item 40) (Figure 7-1). These islands are of varying sizes and characteristics and presently range in age from newly formed ones to those estimated to be 50 years old, Although the majority of the islands were made by the CE, many are owned or managed by other Federal agencies, state governments, conservation organizations, or private citizens. The CE continues to maintain an interest in these man-made islands because of its responsibility in using environmentally acceptable disposal methods and sites, the continuing need for disposal sites, the need for wildlife habitats in waterway areas, and the islands' recreation potential (item 51). The rapid increase in the U.S. population and the corresponding demand on natural resources have helped to cause a gradual change in the use of the islands by wildlife and a need for reassessment of their role as habitats. Natural sites have been altered and occupied by man through industrial, housing, and recreational development to such a large extent that some areas of the United States no longer have coastal islands that are still suitable wildlife habitat. Dredged material islands have provided this vital habitat in many areas.

b. The primary wildlife species needing dredged material islands as part of their life requirements are 37 species of colonial-nesting waterbirds: pelicans, cormorants, anhingas, herons, egrets, ibises, spoonbills, gulls, terns, and skimmers. Several of these species are rare, threatened, or endangered throughout large parts of their ranges (Figure 7-2). An estimated 2 million are nesting on over 700 of these dredged material islands in U.S. waterways, especially along the Atlantic and Gulf coasts from Long Island to Mexico. Islands can offer these birds protection from ground predators, seclusion from man, and nesting substrates similar to those found in traditional nesting sites. The birds are especially vulnerable during the nesting season when they concentrate for several months in colonies and remain in them until their chicks have fledged. These waterbirds are protected by Federal laws since they are migratory species. These laws make destruction, harassment, or disruption of nesting colonies of birds illegal, including those on dredged material sites. State laws often back up these Federal regulations in offering protection to nongame species.

c. In general, the correlation between increases in human populations and decreases in waterbird populations holds true. The only exceptions exist when alternate habitats such as dredged material islands become available. Huge declines in waterbird numbers have stabilized somewhat, partly as a result of the creation of islands, and without which waterbird populations

Figure 7-1. A dredged material island in Florida typical of those built in the U.S. Intracoastal Waterway

Figure 7-2. Endangered brown pelicans nesting on Gaillard Island CDF, their first nesting in Alabama in over 80 years

would be 50 percent or less of present levels (item 73). Detailed research and discussion on islands built of dredged material are presented in items 40 and 73. Guidance for selection of island development as a disposal alternative is presented in Figure 7-3, and details for the selection process are presented in item 72.

7-2. Island Development and Management. Although many colonies of birds presently are nesting on dredged material islands, there are numerous characteristics of these islands that could be improved by management to enhance the available habitat, and there are several ways dredging operations can be altered to benefit the numerous sea and wading birds and other wildlife on dredged material islands. Development and management of dredged material islands for avian wildlife will also usually provide essential habitat for smaller mammals and rodents that use the islands, and covers a broad spectrum of techniques. In some cases, small mammals may act as bird predators, so their colonization should not be encouraged.

a. Habitat Changes.

(1) Basically, development/management of an island for colonial sea and wading birds is concerned with habitat manipulation, habitat establishment, and habitat protection. Manipulation of habitats, by far the most likely technique to be used by engineers, would include proper placement of dredged material to maintain or reestablish habitats, increase the size of existing islands, and/or change configuration, elevation, vegetation, and other features for more desirable habitats. Manipulation of habitats would include, for the biologist, establishment of new vegetation and management of existing vegetation on islands through various agronomic and horticultural techniques.

(2) Establishment of new habitats is desirable when nesting habitat is lacking and new islands must be created, with the resulting need for vegetation establishment; when nesting habitat is expanded by an addition to an existing island which must be established with vegetation; or when undesirable nesting habitats (vegetation) occurring on islands must be cleared out and desirable habitats established in their place.

(3) Habitat protection may be accomplished by island posting or fencing for isolation. Most bird species are already protected by law, but their habitats are not protected except during the time they are occupied by the nesting birds. Year-round protection to prevent destruction of habitat from year to year and seasonal protection to prevent nesting colony disruption by humans and predators are necessary.

(4) Management of existing islands has been demonstrated to be an effective disposal technique and wildlife management practice. Considerable potential exists for the disposal of dredged material and the creation or improvement of avian habitat. Management of existing dredged material islands is most desirable because the potential environmental impacts of disposing on an existing site are less than those of developing new islands.

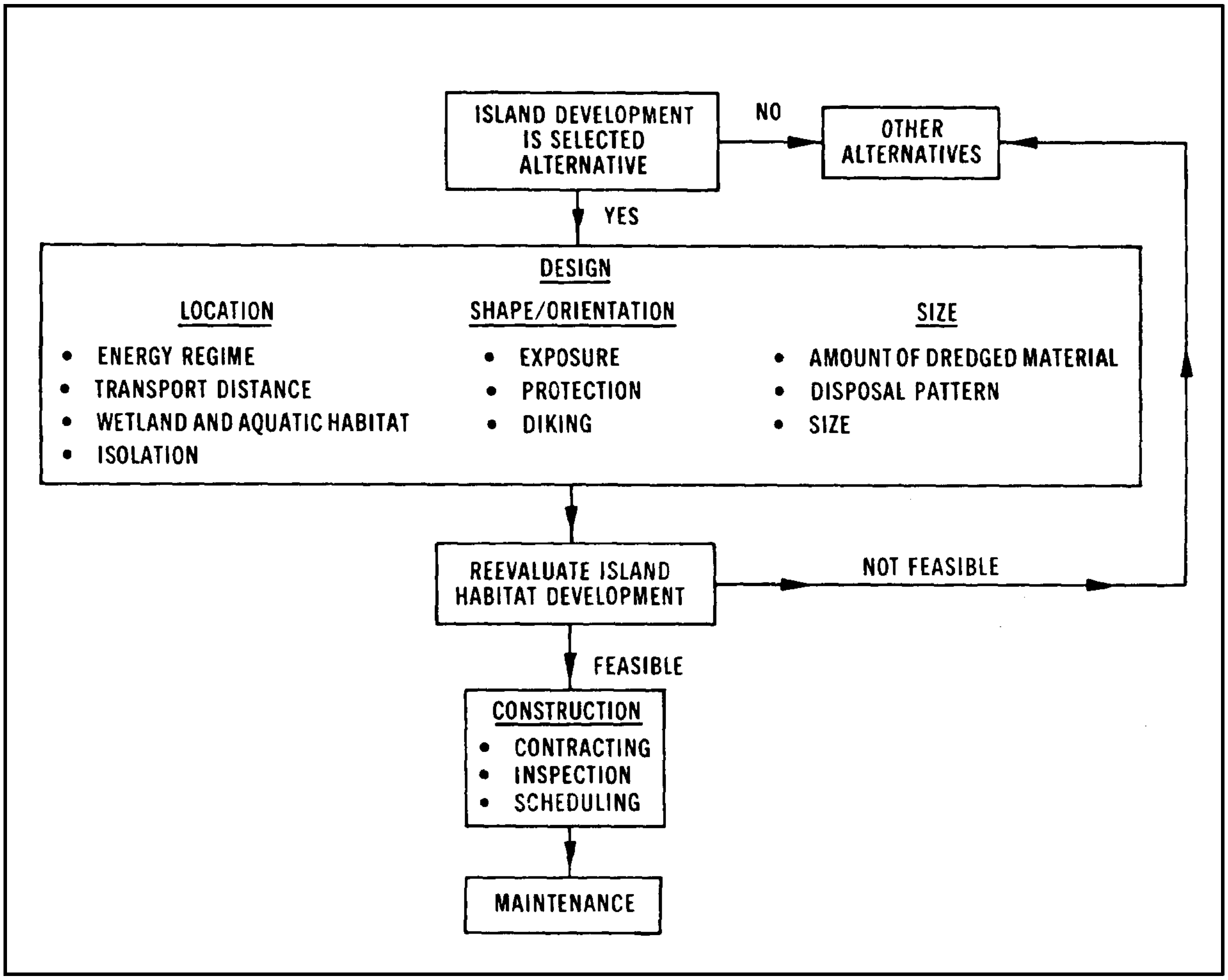


Figure 7-3. Procedural guidelines for selection of island habitat development

b. Use of Dredging Operations on Existing Islands.

(1) The CE has provided habitat incidental to project purpose since the agency first created dredged material islands. Since that time, islands have been kept in various stages of plant succession through dredged material deposition from channel maintenance operations. These operations can have a significant positive impact on waterbird breeding populations (Figure 7-4). Through proper planning the positive impact of regular maintenance dredging could be increased. Since past dredging operations have been carried out with little or no regard for nesting birds, many areas do not have adequate diversity of nesting habitats. Some areas lack ground nesting habitats while others lack woody habitats. Item 73 reports habitat needs that could be satisfied by dredging operations in all the regions studied. Needs for bare ground nesting areas and more tree/shrub habitats exist on almost every part of the U.S. coast. The rate at which various habitats appear on an island after receiving dredged material and an estimate of their longevity have been determined (items 40 and 73).

(2) Once site-specific needs are known, nesting habitat management can easily become a part of the regular maintenance dredging process. To maintain target habitat diversity for certain bird species, islands in any given area would have to be selected to receive periodic depositions of dredged material. Restrictions against dredged material deposition on all or parts of some islands may be necessary in order to allow habitats for tree nesting birds to develop or to preserve existing tree habitats (Figure 7-5). The feasibility of these management recommendations has already been demonstrated by the Wilmington District. They have been practicing such management on a local, annual basis for several years and have developed a long-range colonial sea and wading bird management plan for the lower Cape Fear River estuary which includes maintenance dredging and placement and timing of dredged material depositions on existing islands.

c. Building New Islands.

(1) Construction of new islands would be desirable under some conditions. If it has been demonstrated that there is a need for nesting habitat in an area lacking suitable islands, and if the benefits for the birds will exceed any negative effects of construction of an island to benthic organisms and current flow, then an island could be built. However, islands should not be placed in areas where they would be used for recreational purposes during the breeding season, thus eliminating or severely reducing their wildlife value.

(2) In most areas there is no need for more islands for colonial nesting birds or other forms of wildlife. Management of existing islands should be given first priority. There are areas, however, where additional nesting habitats would be beneficial and existing dredged material and natural islands are not available to fulfill that need. Establishment of need should be

Figure 7-4. Royal and sandwich terns nesting on dredged material islands in North Carolina, where successional vegetation stages are deliberately set back with disposal operations to maintain tern nesting habitat

Figure 7-5. Woody habitat on Little Pelican Island, a dredged material island in Galveston Bay, Texas, which is not often disturbed by disposal, and continues as a heron, egret, spoonbill and ibis nesting colony

determined by consultation with knowledgeable wildlife biologists or by field studies. Generally, construction of new islands for wildlife will not be feasible unless it can be demonstrated that the anticipated positive impacts on the target species will outweigh any negative impacts on the environment. However, it would be desirable to construct a limited number of new islands in various regions of the United States for study purposes and to obtain baseline data. As more natural sites are taken over by man, strategic placement of new sites may become more valuable as a management tool. The present knowledge of bird utilization is based primarily on empirical observations of existing dredged material islands, and more baseline data are needed.

(3) In addition to establishment of need, the feasibility of new island construction will be dependent on the concerns of Federal and state agencies and the private sector. These concerns vary considerably among the regions of the country. However, it has been proven that construction of new islands for birds and other forms of wildlife is feasible. The Wilmington District constructed two islands in Core Sound, North Carolina (Figure 7-6), and the US Army Engineer Waterways Experiment Station (WES) has built or modified several islands for habitat development. The two North Carolina islands were unique in that they were the first to be constructed and placed in a manner to deliberately create habitat for colonial sea birds and aquatic life, and they were retained by the use of large nylon sand-filled bags. The sites were designed so that during future maintenance dredging of the nearby navigation channel, material could be added to them within the existing sandbag retainers, and more sandbags may be added to create higher retention dikes. The kidney shape of the islands formed a small cove where it is expected that a marsh will develop and benthic organisms will thrive. Marsh around the island was given a boost by the planting of smooth cordgrass and saltmeadow cordgrass around the perimeter. The islands were placed in an area with adequate shallow water and food resources but with a scarcity of bare ground nesting habitat. Gull-billed terns, common terns, least terns, and black skimmers nested on the islands during the first breeding season after construction. A number of islands have now been built in Florida, Alabama, Texas, Louisiana, and the Great Lakes with waterbird habitat development as a secondary project goal.

(4) Site location of an island should be worked out with knowledgeable wildlife biologists and concerned agencies to establish the best location. Building an island in an area that does not conform to the biological and engineering specifications outlined herein would fail to produce the desired wildlife habitat. The islands must be placed where the birds will be isolated from predators and human disturbances, unless the islands are going to be actively protected by wardens. With active protection, colonies of sea and wading birds have been successful close to human activities and have provided tourist attractions that could be observed from outside the colony (item 40).

(5) Timing of island development is important. Ideally, an island should be built during the fall or winter preceding the initiation of the next breeding season. The birds generally do not use a site until after the

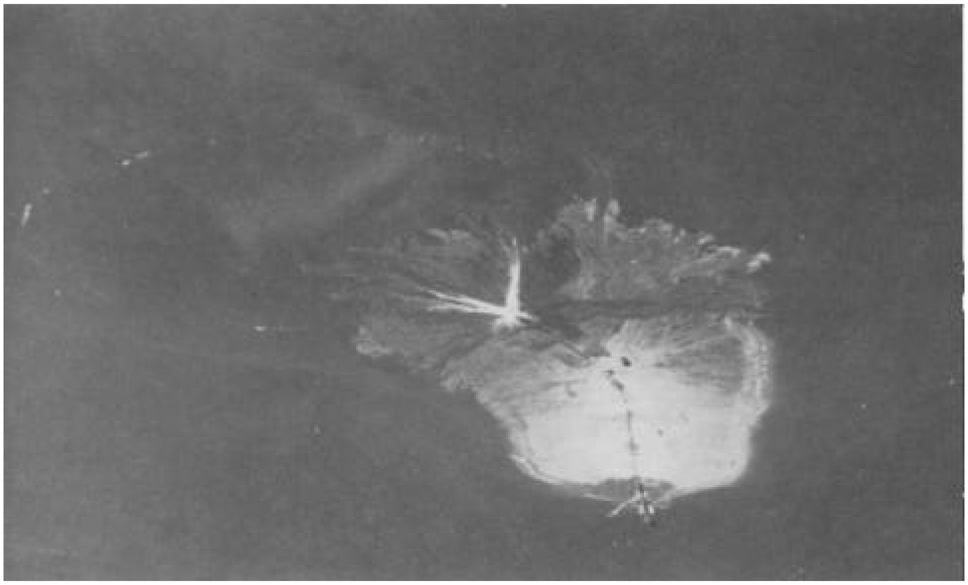


Figure 7-6. A new dredged material island built by Wilmington District in Core Sound in 1977 for seabird nesting habitat. The island is still being used for disposal, and is also a very successful nesting site.

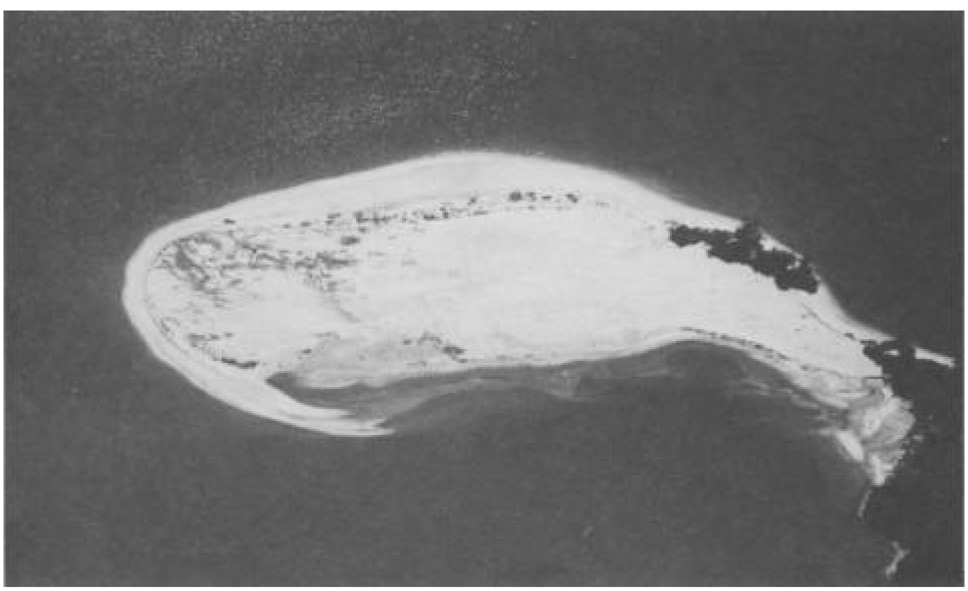


Figure 7-7. An addition built by Jacksonville District to Sunken Island in Hillsborough Bay, Florida, during maintenance dredging operations. It was built as seabird nesting habitat in cooperation with the National Audubon Society.

initial sorting of fine materials by wind and water. If it is built in the spring, this sorting will not have had time to take place, and any colony of birds trying to nest there may not be successful. Their eggs may be covered by drifting fine material. In addition, they cannot use a site until it has had adequate time to dewater.

(6) The physical design of an island is important. In general, islands must be permanently emergent at high water levels; birds have been found nesting on all sizes and shapes of islands as long as they met this crucial breeding requirement. However, observations of hundreds of bird colonies on dredged material islands and the kinds of islands they select has led to four categories of recommendations: size, configuration, substrate, and elevation (item 40). Whether an island is diked or undiked can make a significant difference in bird use.

(a) Ideally, new islands should be no smaller than 5 acres and no larger than 50 acres; however, birds have been found nesting on both smaller and larger islands, and this is a highly site- and species-specific feature. Islands larger than 50 acres would generally be difficult to manage and would also be more likely to support predator populations such as coyotes, snakes, foxes, feral cats and dogs, rats, and raccoons. Islands between the two extremes can be more easily managed, and considerable habitat diversity could be achieved on them. Generally, the greater the amount of habitat diversity to be maintained for wildlife populations, the larger the island should be.

(b) The configuration of an island will depend on the target wildlife species. Steep slopes such as those found on dikes should be avoided for all species. A slope no greater than a 3-foot rise per 100 feet has been recommended (item 73). Substrate configurations for the ground nesting species are given in item 73. Many bare ground nesters must have gentle slopes to prevent their eggs from rolling from nest scrapes. There is also evidence that the formation of a bay or pond with the island makes it more attractive to nesting birds (item 40).

(c) The general nesting substrate requirements of colonial bird species are given in item 73. Generally, coarser materials such as sand or cobble make better nesting substrates due to greater stability. Fine materials such as silts and clays are subject to wind and rain erosion, and usually have desiccation cracks, settling, and ponding. A mixture of sand and shell material makes good nesting substrate for most of the ground nesting birds which prefer sandy beach areas. These bird species historically nested on sandy beaches before being forced off by human use. Fine, unstable dredged material may be stabilized to form suitable nesting substrate by adding coarse materials such as shells over its surface or by planting a ground cover on the material to provide vegetation for those species which prefer that kind of habitat, such as the Forster’s tern or laughing gull. Tree nesting species obviously prefer woody vegetation, and these trees and shrubs often colonize best on silty, more fertile substrates. Selected plant species of shrubs and trees which are discussed in item 73 may be planted on the sites since there are several plant species which seem to be preferred over others by tree nesting birds. If plant propagation is to be a part of a management scheme, these species should be given first consideration.

(d) Elevations of constructed islands should be high enough to prevent flooding of the areas that could be used by waterbirds for nesting. However, elevations do not need to be so high that the substrate will not become stabilized due to wind erosion. Generally, the optimal elevation for an island is between 3 and 10 feet above mean high water. The desirable elevation to be achieved will depend on texture of the exposed dredged material, wind exposure, and the habitat objectives or target species. Coarser materials may stabilize at higher elevations than finer materials. If islands could be constructed of coarser material for ground nesting birds, then it would be acceptable in some cases to exceed the recommended elevation. In general, the higher the elevation, the slower the island will be colonized by plants. Therefore, lower elevations to achieve plant cover for some ground nesting species and all tree nesting species should be considered where those are the target wildlife species and where substrates are of fine-textured material. It should be remembered that given the proper substrates and vegetation for nesting, none of the species using dredged material islands for nesting choose one elevation over another as long as they are above the tide or flood lines.

d. Dredged Material Island Additions, Additions to islands may be a useful management tool if valuable nesting sites are altered by erosion until they have to be eventually abandoned. Additions to such islands will prolong their usefulness as nesting habitats. Additions to islands which are covered with vegetation will increase habitat diversity by providing some bare ground habitat, at least temporarily, for those forms of wildlife requiring bare ground (Figure 7-7). In south Florida, additions may be done in such a manner that encourages growth of mangroves, an excellent nesting substrate for tree nesting birds. Colonies have responded favorably to island additions, especially bare ground nesting species along the gulf and Atlantic coasts.

e. Confined Disposal Facilities (CDFs). In the Great Lakes and a number of ports along the eastern and gulf coasts, CE Districts have constructed large, permanent, diked islands for maintenance dredging. These islands are sometimes over 1,000 acres in size, often well-armored, and in most cases designed for permanent containment of contaminated sediments, especially along the mid-Atlantic to New York coast and in the Great Lakes. These islands are located up to 3 miles from shorelines and are relatively isolated. From the time of their construction, they have been used more and more by nesting and loafing seabirds. Jacksonville, Mobile, Detroit, Wilmington, and other CE Districts considered seabird use in design and management on newer CDFs, and the seabird colonization has been spectacular in several cases. Management on CDFs generally consists of continued protective isolation, wildlife monitoring, and posting. Vegetation management has not yet become a problem on any of these relatively new islands.

f. Protection of Bird Colonies.

(1) Since the primary users of dredged material islands are the sea and wading birds which nest in colonies, and the lack of isolation and protection is one of the primary problems these birds face, this species group would be greatly benefited by the provision of protection of colonies and nesting areas. They are already protected by Federal law and regulation as migratory species. Since this does not protect habitat unless the migratory animal is present, it can sometimes be detrimental for long-term protection purposes. In addition, some states have laws and regulations designed to give protection. A number of endangered or threatened species nest in colonies on dredged material islands. It has been shown repeatedly throughout North America that, in general, protected colonies are successful and unprotected colonies are not. Every Federal and state agency and individual has the responsibility to see that its actions are not in violation of laws which protect wildlife. To ensure compliance with the law, maintenance operations involving placement of dredged material should be conducted in a manner which will not disturb the bird colonies. Management should include proper care during placement of dredged material, surveying, and dike construction.

(2) Public education concerning the vulnerability of colonial-nesting birds has the potential of being a valuable management tool. Through various public affairs channels, the general public could be made aware of the value of dredged material islands to colonial birds. At the same time they could be informed that the continued disposal of dredged material may be a viable management option.

(3) Other protective measures for colonies which are valuable management tools include posting of colonies with signs such as those used by Mobile and Portland Districts, fencing, designation of certain colonies as sanctuaries, limiting of scientific study (and thus disturbance of the birds by constant observation and measurements), and control of wildlife predators such as raccoons, foxes, and feral animals.

g. Vegetation on Dredged Material Islands.

(1) A number of suitable plant species could be planted on islands that would increase the islands' attractiveness to wildlife and especially to colonies of nesting sea and wading birds (items 39 and 73). Depending upon the wildlife species specific requirements, a variety of suitable plants could be used in a management plan for islands. No plantings would be necessary for ground nesting species in most cases, although some of these species use sparse herbs and grasses for nesting. Since tree nesting species require tree/shrub habitat, planting of this vegetation type on islands would hasten wildlife use by more quickly providing suitable habitat. Woody habitat will require 5 to 30 years to develop, depending upon the region and climatic conditions.

(2) Another aspect of vegetation on islands is that sometimes it must be controlled in order to provide the proper or desired habitat for target wildlife species. Vegetation control would be necessary if habitat for ground nesting species was scarce and there was an abundance of other habitats or if the wrong species of trees were growing on an island that precluded nesting or other wildlife use. Some of the control methods that have been successfully tried on dredged material islands are mechanical removal (tractors, tillers, chain saws, axes), hand removal (pulling up plants by their roots), controlled burning, and applications of herbicides. Controlled burning is not very successful because new growth will begin immediately. Herbicides should be carefully applied according to directions; they have been found to be extremely effective on islands in North Carolina.

7-3. Development and Management Problems.

a. Numerous potential problems may be encountered in building and/or managing dredged material islands. A key to success in the early planning stages is cooperation and coordination with Federal, state, and local agencies with regulatory authorities. Many obstacles to project success could be removed by correct planning and public awareness efforts before the project actually begins.

b. The development of specifications for dredged material disposal to develop islands for habitat and simultaneously satisfy the need to dispose of a given amount of dredged material requires considerable care. Specifications should include: exact locations, time of disposal, size of deposit, elevation of deposit, and movement of disposal pipes to ensure that habitat plans are carried out. Onsite monitoring is highly desirable and is necessary when disposal is onto an island with an existing bird colony or population of vulnerable wildlife.

c. Silt curtains (effective only in certain parts of United States under certain soil conditions) or temporary dikes sometimes may be required in disposal activities, and if a dike is built on an existing island and filled, the dike should usually be at least partially removed or breached to allow ground access to water by young birds. This will require return to the site by earth-moving equipment. Dikes do not need to be erected until just prior to disposal use for best use by wildlife. Periodic monitoring to determine aftereffects of disposal will provide useful information for future disposal efforts.

d. The public is seldom aware of wildlife needs. Severe damage can be inflicted on a colony by simply fishing or boating adjacent to an island during the nesting season through disturbance of young and adults. Surveying and dike construction activities could also disrupt nesting birds. Education of both the general public and dredging personnel is needed. An information program should be a part of every ongoing or planned dredging operation. Positive public opinion regarding disposal operations of dredged material in North America may improve public acceptance and understanding of dredged material disposal operations, and allow more of this resource to be developed for the benefit of North American wildlife.

CHAPTER 8

AQUATIC HABITATS

8-1. General.

a. Aquatic habitat development is the establishment of biological communities on dredged material at or below mean tide in coastal areas, and in permanent water in lakes and rivers. Potential developments include such communities as tidal flats, seagrass meadows, oyster beds, clam flats, fishing reefs, and freshwater aquatic plant establishment. This habitat development alternative has great potential that is just now beginning to be realized through various District projects. The bottom of many water bodies potentially could be altered using dredged material; this could simultaneously improve the characteristics of the site for selected aquatic species and permit the disposal of significant quantities of material (item 72).

b. A number of applications of this alternative have been made by CE Districts in recent years, including development of razorshell clam sites in Portland District, creation of gravel riffles in the Tennessee-Tombigbee Waterway in Mobile and Nashville Districts, razor clam and mussel habitat in St. Paul District, and establishment of artificial fishing reefs in a number of Districts. Unsuccessful attempts to establish seagrasses on dredged material have been made, and is a concept to be reattempted using the newest techniques and very careful site selection.

c. The recent creation of an underwater berm using coarse-grained dredged material has been tested at Virginia Beach, Virginia, in Norfolk District. This will not only provide aquatic habitat, but will serve to protect the shoreline through storm wave dissipation, sand stockpiling for beach nourishment, and allowing a reduction in maintenance dredging in some tidal inlets. Three smaller sites have also been developed as underwater berms for aquatic habitat: Thimble Shoal, Virginia, in Norfolk District; Kings Bay, Georgia, in Jacksonville District; and Charleston Harbor, South Carolina, in Charleston District.

8-2. Aquatic Habitat Development. Limited aquatic habitat development has been tested in Florida (items 72 and 77), the Great Lakes, and several west, east, and Gulf coast Districts. It is a still-developing concept, with much still unknown about what is likely to be encountered or considered at any site. Each aquatic habitat site should be approached as a unique situation until further guidelines are made available.

a. Advantages. Several advantages to aquatic habitat development are recognized. It provides high biological production, has a potential for wide application, complements other habitats, and provides habitat where none previously existed or had been destroyed. Aquatic habitats may be highly productive biological units. Seagrass beds are recognized as exceptionally valuable habitat features providing both food and cover for many fish and shellfish. Oyster beds and clam flats have high recreational and commercial importance. Fishing reefs built on flat, relatively sterile lake, river, or bay bottoms provide habitat diversity, food, and cover, as well as recreation for fishermen. Dredging material disposal projects impacting aquatic communities predictably incur strong criticism, and in these cases reestablishment of similar communities may be feasible as a mitigation or enhancement technique. In many instances it may be possible to establish aquatic habitats as part of a wetland habitat development project. This concept potentially has very wide application, as most dredging projects are flanked by open water. Often, the selective subaquatic placement of material will both enhance the disposal site and accommodate large amounts of dredged material. In the case of fishing reefs built of dredged material, the material is usually bedrock or rubble from new work dredging operations suitable for reef formation. This kind of dredged material is also well suited for oyster and clam bed development since it gives oysters and clams places to attach.

b. Disadvantages. The primary and overriding disadvantage of aquatic habitat development is an inadequate understanding of techniques for applying this alternative. Careful site-by-site determination combined with local biological and engineering expertise is necessary. Seagrass establishment to date has largely been on disturbed sites that did not involve dredging (items 76 and 77), and its application to disposal sites thus far has been very limited. Development of freshwater aquatic habitat has been limited to providing protective structures via barge-transported coarse-grained material to allow natural plant development, in the case studies listed in para 8-lb.

8-3. Guidelines for Aquatic Habitat Development. The lack of more specific engineering and environmental guidance on aquatic habitat development should not eliminate the consideration of this alternative. References which provide guidance by experts in coastal areas include items 64 and 76-78. Most aspects of habitat development presented in the preliminary assessment and the detailed evaluation of feasibility (Figure 4-6) will be applicable to aquatic habitat development. Of particular significance will be hydraulic energies along the bottom and circulation patterns. The interaction of the texture of the material with the hydraulic energies of the site will be significant, as the material must provide a stable surface substrate. The possibility that alteration of the bottom configuration of a waterway could adversely affect current patterns should be carefully considered, especially with fishing reefs and protective structures for freshwater aquatic plants. In large projects or in those projects where some question exists regarding the impact, it may be advisable to develop physical, chemical, and biological models of the aquatic system prior to project implementation.

8-4. Design of Seagrass Habitat. There are few well-documented examples of seagrass habitat development on dredged material, though a few successful transplants have been made in southern California and on one site in Florida. Revegetation of reclaimed subtidal bottom has been successfully accomplished (item 76), and results from these projects can be applied to dredged material.

Transplanting techniques are described in item 76. Figures 8-1 and 8-2 show the coring method of transplanting plugs, in this case, of shoal grass at Port St. Joe, Florida. Figure 8-3 shows a bareroot propagule of eel grass. Figure 8-4 shows turtle grass being transplanted into sand. Seagrass development will help stabilize dredged material through the binding action of roots and rhizomes, and in the dissipation of wave and current energy, thereby reducing erosion processes.

a. Location. Seagrasses normally occur along shorelines with low wave and current energies. Development of seagrass habitat in higher energy areas will require permanent protection with breakwaters or planting within lagoons created within dredged material islands.

b. Depth. Bottom elevations within seagrass beds extend from mean low water to -2 m in estuaries and -10 m in coastal environments.

c. Water Quality. Surveys to predict expected annual fluctuations in water quality at a site will be needed to assess suitability. Data should be collected as frequently as possible so that the site can be adequately characterized. Presence of natural seagrass beds in the vicinity of a proposed site will also be a strong indicator of general water quality suitability.

(1) Light. The foremost need of seagrasses is sufficient light penetration through the water column to support growth. High water column turbidity is an indication that a site is not suitable for habitat development.

(2) Salinity. Most of the common species of seagrasses require salinities greater than 20 ppt, though some local variations may exist where plants tolerate salinities as low as 10 to 15 ppt.

(3) Temperature. Though seagrasses require relatively low-energy environments, the area needs to be well flushed and currents must circulate to prevent lethal temperature extremes from occurring.

d. Sediment Type. Sediment grain size is not usually a limiting factor, as most seagrasses can tolerate a wide range in sediment from coarse sand to mud.

e. Vegetative Establishment.

(1) Plant selection. In most geographic regions, species selection will be based on salinity, though along the southeast Atlantic and Gulf coasts where two or three seagrass species occur, other considerations need to be made. In this area, environmental tolerances or species growth rate may be a prime factor in species selection (item 48).

(2) Propagule selection. Seagrass habitat development is almost exclusively restricted to transplanting mature plants from a donor bed, as nursery

Figure 8-1. Removing plugs of shoal grass from an existing bed near Port St. Joe, Florida. They were transplanted on a nearby dredged material site.

Figure 8-2. Temporary storage for the shoal grass plugs was provided by containers of seawater, which were transported to the dredged material site by skiff.

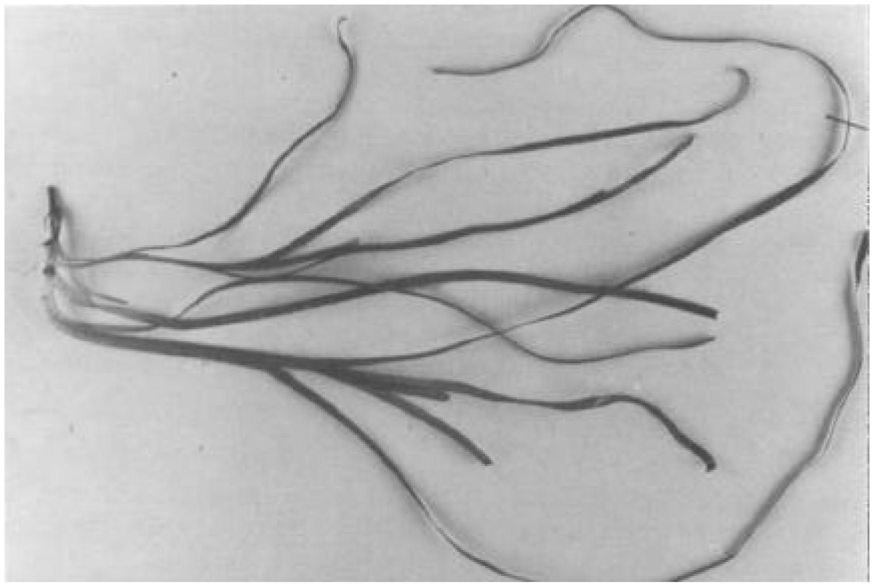


Figure 8-3. A bareroot propagule of eel grass ready for transplantation. This is the most efficiently handled and cost effective type of propagule.

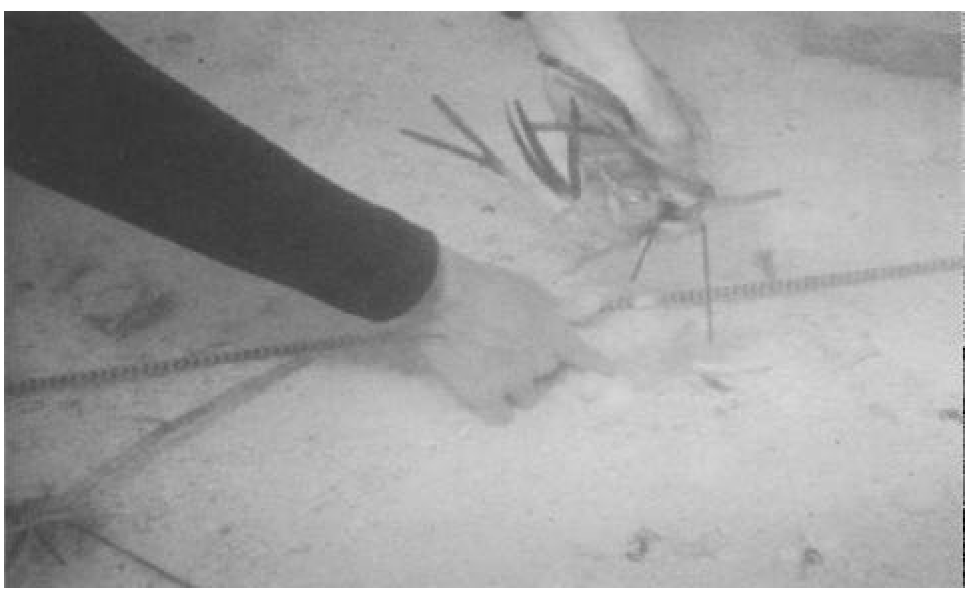


Figure 8-4. Transplanting a bareroot propagule of turtle grass on a sandy site. The transplant is held in place with a long staple, which prevents waves and currents from washing it out.

stock is currently unavailable. Mature plants reproduce by branching. Methods using seeds or seedlings have not been adequately developed.

(3) Plant spacing. The rate at which seagrass will cover the bottom is dependent on species growth rate and spacing of transplants. Some species are much faster growing than others. Spacing guidelines can be found in item 76.

(4) Handling plant material. Plants need to be handled as carefully as possible to avoid damage to roots and shoots. Turtle grass meristematic tissue protection is critical for that species' reproduction. Short-term plant storage (hours) can be in well-aerated containers, while longer term storage (days, weeks) should be in floating pens or flowing seawater tables. Plants should never be directly exposed to sun and air for more than a minute or two.

(5) Pilot propagation study. In a seagrass development project where there are unknown factors such as water quality, rate of plant spread, or lack of experience in similar projects, it is prudent to conduct a pilot study. A pilot project is particularly advisable if the project is a large and costly one. A pilot study's main purpose is to determine whether or not the propagules will grow under conditions found on the site. The study can be conducted in less than a year, but the test species should be allowed to grow for one full season before conclusions are drawn. Such a project should be of sufficient size that it will accurately reflect future operational difficulties. The size of the pilot study is limited only by the desired tests, the time available for such testing, and funding. A simple statistical design will permit quantitative evaluation of the study where prediction of degree of success or failure can be made. The success of these plants can generally be evaluated by observation of survival. Test plots established should be evaluated on a regular basis to determine survival and growth.

(6) Time of planting. Almost without exception, spring is the best time for planting seagrasses. Transplanting can be successful in other seasons, but with less overall survival.

CHAPTER 9

BEACHES AND BEACH NOURISHMENT

9-1. General. Shore erosion is a major problem along many ocean beaches and the shoreline of the Great Lakes. One of the most desirable, cost-effective shore protection alternatives is beach nourishment (Figure 9-1). Beach nourishment is usually accomplished by borrowing sand from inshore or offshore locations and transporting the sand by truck, by split-hull hopper dredge, or by hydraulic pipeline to an eroding beach. These operations result in massive displacement of the substrate, changes in the topography or bathymetry of the borrow and replenishment areas, and destruction of nonmotile benthic communities. However, a well-planned beach nourishment operation can minimize these effects by taking advantage of the resiliency of the beach and nearshore environment and its associated biota, and by avoiding sensitive resources (item 67).

9-2. Types of Beach Nourishment. Four major types of beach nourishment occur along U.S. shorelines: new borrow material not connected with maintenance dredging, maintenance dredging of an existing channel, dumping in the littoral zone to allow beach nourishment, and rehandling of stockpiled material.

a. Borrow Dredging. This type of dredging entails removal specifically for beach nourishment. The major physical impact of dredging borrow material is the mechanical disturbance of the substrate and the subsequent redistribution of suspended sediments and turbidity. Suspension of sediments and turbidities is usually a short-term impact. Once dredging ceases, heavier sediments rapidly settle, and fine sediments are dissipated by waves and currents. Sea bottom borrow pits remain intact for long periods of time unless currents transport sediments into the pits and fill them. If the borrow pits are in an area of low wave energy and the surrounding bottom sediments contain high levels of organic materials, the pits are likely to slowly fill with the organic-laden sediments. Decomposition of the organic material in these pits may result in anaerobic conditions and generally poor water quality.

b. Maintenance Dredging. The use of maintenance dredged material for beach restoration can serve two beneficial purposes: disposal of the material, and restoration of an eroding beach. If such material is selected, it should closely match the sediment composition of the eroding beach and be low in fine sediments, organic material, and pollutants. Sediments containing large quantities of fine materials result in high turbidities and may introduce trace metals and other contaminants into the water. High turbidities and sedimentation may inhibit reestablishment of beach animals that have a specific habitat requirement or may prevent recruitment to the beach by pelagic larvae, particularly if beach restoration occurs during the peak spawning season in spring and early summer. The disposal may interfere with the selection of a nesting beach by sea turtles if beach sediments are significantly changed, and the appearance of such sediments is aesthetically displeasing.

Figure 9-1. A beach nourishment operation under way at Mayport, Florida

Figure 9-2. A sea turtle hatchling moving toward open water on
a Florida dredged material beach

c. Dumping in the Littoral Zone. Disposal of dredged material can be by deliberate placement on the sea bottom, where it will be carried by currents and waves to the beach. The dredged material will replenish the eroding beach in a natural manner as it is carried by wave energy. Material can be placed in the littoral zone by hydraulic pipeline or by split-hull hopper dredge.

d. Rehandling Stockpiled Material. Coarse-grained dredged material can be pumped into a holding area, where it is allowed to dewater. Then it can be moved by truck or heavy equipment onto the eroding beach. This technique is commonly applied in small restoration projects.

9-3. Environmental Considerations.

a. Impacts on Beach Organisms.

(1) Animals on high-energy beaches are subject to the effects of seasonal sediment erosion and accretion and major physical changes related to storms. In the Pacific Northwest, animals may be stressed to the 60-foot contour. Beach animals are adapted to survival under these stressful conditions, whereas those animals offshore are generally in a more stable environment and are less adapted to a high level of sediment movement. Burial of nonmotile benthic animals by replenishment material placed on the beach, or material being transported offshore from the beach, is usually lethal unless the animals are able to migrate through the sediment overburden and escape. Laboratory studies have shown that some benthic animals (especially bivalves) can migrate vertically through more than 1 foot of deposited sediment. The ability of benthic animals to survive burial by dredged material will depend not only upon the depth of the sediment, but also upon the length of time the animals are buried, time of year, sediment grain size, quality of the sediment, and other specific requirements of the animals. Therefore, rate of survival will vary from location to location.

(2) Beach nourishment creates new habitat that is uninhabited by benthic animals, except for those that may have survived being pumped to the beach with the dredged material or those that survived by vertical migration through deposited sediments. A beach nourishment operation is generally followed by rapid establishment of new benthic populations. Many of these are opportunistic species that develop large population densities, then decline as other species are recruited which are more adaptable to the new habitat. The time for the resident species to become established is referred to as the recovery time of the nourished area (the time required to approach a stable animal population level). Recovery time varies, depending upon type of recruitment of benthic animals. Those animals that have planktonic larvae or can migrate from nearby areas into the nourished area will establish rapidly, whereas those that spend their entire life cycle within the sediments may be slow in recovering. Once beach restoration ceases, recovery of benthic animals is generally rapid, and complete recovery usually occurs within one or two seasons.

(3) The sediment type used for nourishment and the season of year the nourishment takes place are critical to the recovery rate. If the dredged material is different from the natural beach sediment or contains large quantities of fine material, there may be a major change in beach biota, and it may require a long period of time before local resident populations can be reestablished.

b. Impacts on Offshore Organisms. Potentially, the most serious impact of offshore dredging is the loss or damage to major commercial species of benthic shellfish, seagrass beds, corals, and sea turtles. Damage can be minimized by proper selection of borrow areas, by precisely positioning the dredge to avoid these sensitive resources, and by using dredging equipment that minimizes sedimentation and turbidity, such as a suction dredge.

(1) Benthos.

(a) Repopulation of a dredged area by benthic animals will depend upon the magnitude of the disturbance, the new sediment interface, and the water quality in the borrow pit. Borrow pits will be recolonized by migration of animals from adjacent areas and by larval transport. Stability of the environment and bottom sediment type after dredging are major factors in determining the level and rate of species recolonization. It is extremely important to remember that if bottom sediments are significantly changed from the natural sediments, the reestablished populations may not be of the same magnitude or species composition as those prior to dredging.

(b) Offshore borrow pits that accumulate organic material and acquire high concentrations of hydrogen sulfide and low concentrations of dissolved oxygen in the water are- generally very poor quality aquatic habitats. They also usually take a long time to recolonize by benthic animals, or may never recolonize.

(2) Corals.

(a) The ability of corals to recover from beach nourishment is related to the extent of reef damage. If a reef is heavily damaged by equipment being dragged across the reef, by being-covered with sediments, or by all corals being killed, the reef can take a long time to recover, or it may never recover. It has been shown that corals may recover if the damage is not too extensive. Corals along the Florida Atlantic coast damaged during beach nourishment apparently recovered by 7 years after the dredging operation.

(b) Corals along Florida and Hawaii coasts are susceptible to direct physical damage by dredging and to sedimentation and reduced light unless dredging operations are carefully planned and executed. With proper planning and control, dredging impacts on corals can be minimized. One of the most significant impacts on corals results from dragging of anchors and cables, which collapse the reef and destroy benthic animals. Erosion and scour at the base of the corals in the dredged area also may damage corals. This can result in the corals slumping or tilting, or forming overhangs that tend to break off. Reef coral recovery is very slow.

(3) Fish and motile invertebrates.

(a) The mobility of fish and some invertebrates renders them less vulnerable to the adverse effects of beach nourishment than the nonmotile benthic communities. When disturbed by beach nourishment, motile animals will generally leave the area. Those animals that do not leave or are susceptible to suspended sediments in the water can be killed by coating of their gills, leading to anoxia, or if they spawn in the area the sediments may cover their eggs or delay hatching time of their eggs. Feeding habits also may vary according to length of exposure to suspended sediments. Filter-feeding fish are more vulnerable to siltation than bottom feeders.

(b) Destruction of habitat rather than suspended sediment seems to be a greater potential problem to fish. Those fish which are either closely associated with the beach for some part of their life cycle for spawning (i.e., California grunion) or some burrowing and reef-dwelling species with limited mobility (i.e., the dusky jawfish on the Florida Atlantic coast) are more likely to be adversely affected. Beach nourishment operations at Imperial Beach, California, did not prevent subsequent spawning of the grunion; however, on the Florida Atlantic coast it may have displaced the dusky jawfish.

(c) Loss of benthic animals due to sediment burial may indirectly affect motile animals that prey on them. This was suspected to have occurred following a nourishment project on the North Carolina coast. Nourishment occurring during the peak season of beach animal recruitment delayed population reestablishment for several months. During this period, fish and shellfish that usually feed in the surf zone were not observed. Nourishment may also have had short-term benefits to some fish by suspending additional food materials, and the associated turbidities may have provided protection from predators to some motile animals. Studies have shown that moderate to complete recovery of motile animals will usually occur within less than a year unless a required habitat or food source is permanently lost. Fish have been observed moving into an area within the first day after a disturbance.

(d) Mobile animals will be least affected by borrowing operations because of their ability to avoid a disturbed area. Studies have shown that fish will leave an area of active dredging and return when dredging ceases. Whether fish will continue to use a borrow pit as habitat depends upon water quality in the pit. If the pit accumulates anaerobic sediment that results in poor water quality, fish will avoid the pit. However, fish may be attracted to a dredged area as a result of suspended food and as a haven from the cold surface water during the winter. The sediment plume from the dredge may also provide protection to some motile animals. Total recovery at a dredged site, therefore, is variable and ranges from immediate for some species to a year or more for others, depending upon the nature of the habitat modification.

(4) Sea turtles.

(a) Sea turtles are one of the animals most vulnerable to the effects of beach nourishment on the South Atlantic and Gulf coasts (Figure 9-2). Turtle nesting on the beaches and replenishment operations occasionally conflict in these areas. There is concern that turtle nesting and hatching success may be adversely affected by beach nourishment.

(b) Sand particle size and sand compaction have been found to influence nest site selection by some sea turtles. Aborted nesting attempts (false crawls) have occurred on rebuilt beaches in Florida. The precise effects of beach nourishment on nesting sea turtles have not been documented because of insufficient studies. The present limited data indicate caution should be taken in rebuilding beaches that are known to be major turtle nesting sites. It would be best to avoid turtle nesting beaches from April through November, the period which encompasses all of the sea turtles' nesting and incubation season. Such operations must be closely coordinated with U.S. Fish and Wildlife Service (FWS), National Marine Fisheries Service, and state agencies.

(c) Hibernating or aestivating sea turtles have been captured and killed by trawls and dredges. Turtles that are not hibernating or aestivating should be able to avoid a dredge and move back into an area when dredging ceases. If hibernating sea turtles are located, dredging should cease until the operation can be coordinated with FWS.

(5) Seagrass beds. As with corals, caution should be taken to avoid these highly productive areas. Both the actual dredging operation and turbidity caused by adjacent dredging will destroy seagrasses. Seagrasses are usually very slow to recover, if they ever recover. To date, seagrass transplantation has not been refined to a point where a high-percentage survival of transplants and economic feasibility justify efforts to restore large areas of destroyed seagrasses (See Chapter 8). Dredging cautions for corals should also apply for seagrasses.

c. Timing. Timing of the nourishment operation may also be a critical factor in reestablishment of benthic animals. If nourishment occurs during spring and early summer, recruitment of planktonic larvae may be inhibited. High turbidities and unstable substrate are known to preclude larval settlement, thus delaying recovery time of benthic animals. The best time ecologically for beach nourishment and borrowing is during the period of lowest biological activity. This is usually during the winter when there would be minimal effect on the adult and developmental stages of most nearshore and beach animals. Adults have usually migrated out of the area and would be less concentrated in the shallow beach zone, and the nesting and spawning season of beach animals would have passed. Nevertheless, it is still necessary to ensure that no sensitive nonmotile animals are in the area.

d. Dredged Material Substrates. Sediments to be used as material should match the natural beach sediments and should be low in pollutants.

This recommendation is particularly important when maintenance dredged material is used for beach nourishment. Minimum damage to beach animals will occur when clean sand is placed on a sandy substrate, whereas damage to the benthic animals would be great if fine sediments high in organic material are used. Changes in the sand particle size on ocean beaches, should they occur, may also influence site selection and nesting of the threatened and endangered sea turtles.

e. Equipment in Sensitive Areas.

(1) If it can be avoided, the cutterhead on a suction dredge should not be used in the vicinity of live coral reefs or other light-sensitive resources, unless barriers are established to separate the dredging site from them. The suction dredge without a cutterhead is a better choice because siltation is minimized and there is less potential for physical damage to the reef. The dredge should be positioned within the designated borrow area and should not cross a live coral reef, commercial clam bed, or other valuable resources. Cables, anchors, and discharge pipes of a dredge should be positioned in sand or another nonsensitive habitat. Local directions in tidal flow and current should be determined prior to dredging, and the operation adjusted to prevent sediments from crossing live coral reefs or other sensitive resources.

(2) Consideration should be given to shallow dredging over a large area in a low wave energy environment rather than deep dredging which may create a stagnant borrow pit which will require a long time to recover or may never recover. Although ecological damage from dredging the shallow pit would initially be greater, recovery should be faster in the shallow dredged area.

f. Monitoring. Biotic surveys should be made at beach restoration and borrow sites. As an absolute minimum, a preproject baseline survey should be made to identify and locate natural resources, i.e., corals, commercial clam beds, sea turtle nesting beaches, fish spawning areas, and seagrass beds, to aid the planner in avoiding potential damage to these resources.

CHAPTER 10

AQUACULTURE

10-1. General.

a. The CE interest in aquaculture stems from its basic mission in construction and operation of navigable waterways. Due to the increasing difficulty and expense of obtaining dredged material containment acreage for use as single purpose areas, the development of a multiple-use strategy such as aquaculture is desirable. It is possible that future site availability would be improved by increased value of acreage leased to dredging project sponsors because landowners could enter separate and profitable lease agreements with aquaculturists. Aquaculture is attractive because of the potential for: (1) producing nutritious low-cost protein; (2) partially satisfying increased demand for seafood in the United States; (3) increasing employment in fish farms, feed mills, processing plants, and other supporting industries; and (4) providing larval stock for commercially and recreationally important natural populations currently stressed due to pollution and habitat loss. Aquaculture activities would also generate a more positive public image of the CE and its activities.

b. Aquaculture in a dredged material containment area was first explored by the CE during the Dredged Material Research Program. In 1976, Dow Chemical Company, under contract to the CE, successfully cultured a crop of white shrimp in an active containment area near Freeport, Texas (Figure 10-1). This project demonstrated that dredged material containment site environments are compatible with aquaculture in the sense that animals will grow, survive, reach marketable size, and be of marketable quality. No attempt was made to justify the project’s production economics; the cost of postlarval white shrimp stock, the limited acreage, and the small size of the unfed white shrimp at the time they were harvested all contributed to high production costs (item 52).

10-2. Aquaculture Concept.

a. Advances in Technology. Many of the technology problems which affected production economics during the 1976 dredged material demonstration at Freeport, Texas, have been reduced through continuing research on the biology and culture requirements of desirable plant and animal species. It is now possible, for example, under laboratory conditions, to duplicate the life cycle of the white shrimp species used in that study. One advantage of this technology is a reduced cost of obtaining juvenile shrimp compared with the cost of field excursions for capturing egg-carrying and recently mated female shrimp in the wild, and returning them to a laboratory for spawning. Another very significant advantage is that artificial control over the natural reproductive cycle permits production of juvenile shrimp whenever they are needed and allows production of multiple crops in a single growing season.

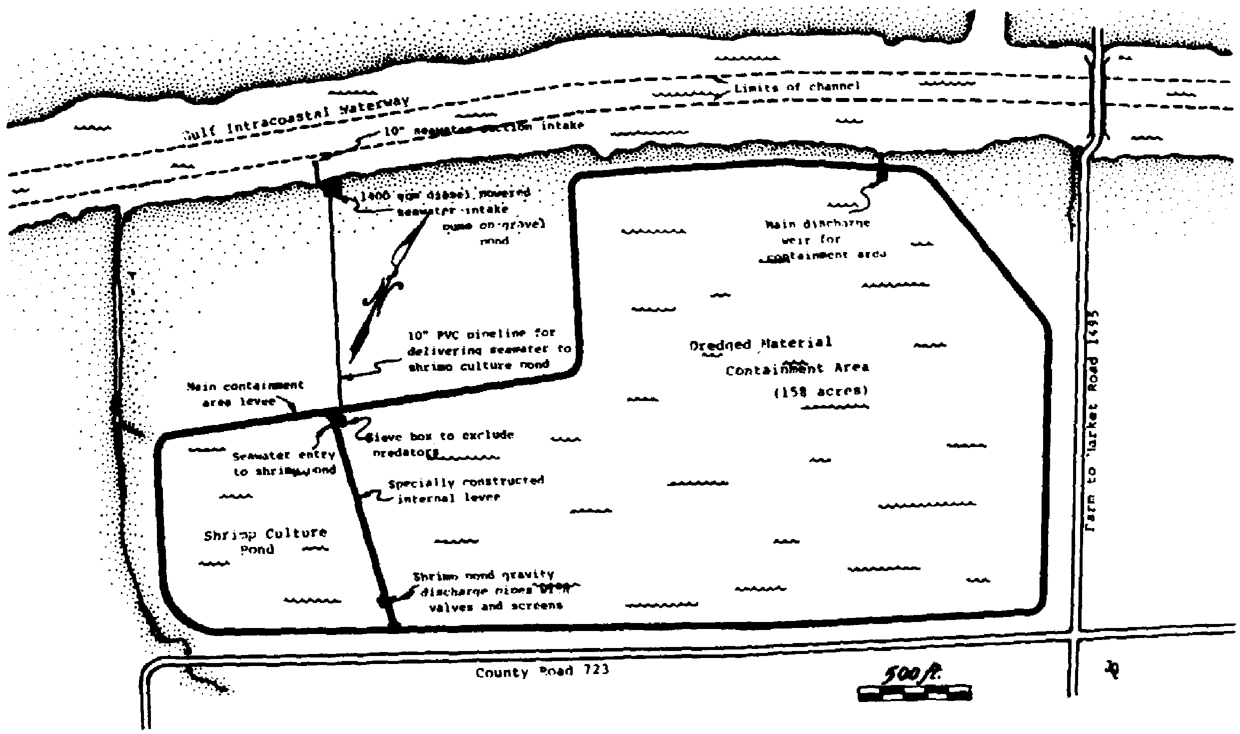


Figure 10-1. Galveston District dredged material Containment Area No. 85, showing the shrimp pond, internal levee, and associated structures

The result is more efficient use of the cultivation area, higher annual production, and lower net production costs.

b. Favorable Economics.

(1) Dredged material containment sites commonly possess structural features such as dikes and water control devices that may enhance their suitability as aquaculture areas. In some instances, land acquisition costs (purchase or lease) and dike and water control structure costs are absorbed wholly or in part by the Federal government or a local cooperator on the dredging project, such as the city government or port authority. In cases where a Federal or local subsidy exists, the aquaculturist could be the beneficiary. The lack of available coastal sites has been one of the principal restraints on the application of commercial aquaculture techniques. This is due both to the cost of real estate and to the Government’s regulatory permitting process which affects consideration of aquaculture in coastal lowlands, particularly wetlands. Freshwater and coastal dredged material containment areas have several benefits related to desirable location: (a) proximity to favorable water sources, (b) waterfront property use that may otherwise be unavailable to the aquaculturist, and (c) nearness to large market areas and established transportation routes.

(2) Dikes that would serve to contain the dredged material would also serve to impound the water necessary for aquaculture. However, dikes of an existing containment site that is under consideration for aquaculture may have to be modified to increase their height, adjust their slopes, or improve their water-retaining capabilities. At a new containment site, the dikes could be designed to permit both the containment of dredged material and the retention of water for the aquaculture operation. Water control structures that are used to regulate water quality at containment areas could also serve to regulate water exchange rates and levels in an aquaculture pond, and could be used to drain the pond or concentrate the crop for harvesting.

10-3. Aquaculture Considerations.

a. Compatibility Between Aquaculture and Dredged Material Management.

(1) There are at least two general containment site management techniques that could be compatible with aquaculture. Figure 10-2 depicts the placement of dredged material into a containment area surrounded by a single primary dike system. Distribution of the dredged material would be dependent on the size (surface area) of the containment, the relative volume and physical characteristics of the dredged material, and the use of controlled disposal operation conditions such as pipeline placement and movement. It is unlikely, though not impossible, that culture operations could be sustained within the site during active disposal. A small volume of dredged material disposed into a large disposal site containing a species tolerant of suspended sediments is one workable scenario. Figure 10-2 also depicts a containment site divided into multiple compartments or cells which would be filled

sequentially over the life of the disposal site. Construction of secondary, internal cross dikes produces a configuration with numerous operational advantages over an undivided one. The most obvious benefit would be related to the separation of one or more cells from dredged material disposal operations. The second configuration has an additional benefit in a new site because it also separates the aquaculture operation from potentially contaminated dredged material. This is a source of perceived, if not actual, production or marketing problems.

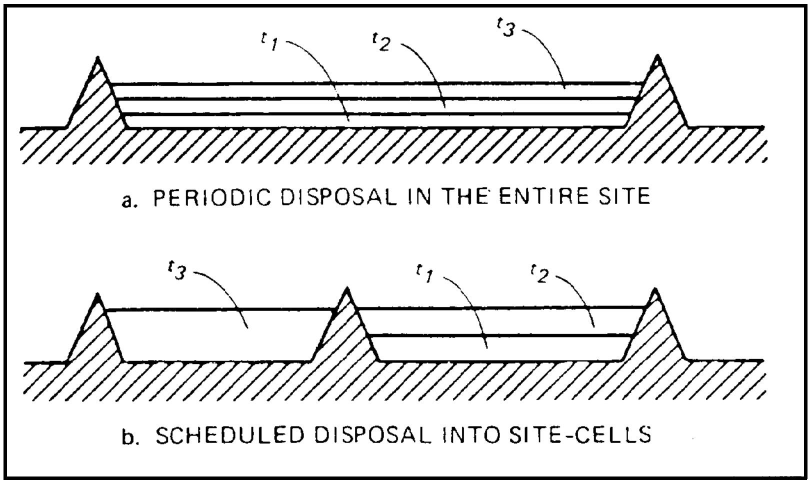


Figure 10-2. Two concepts for combining dredged material containment and aquaculture operations (t = time in years and may vary between 1 and 15 from site to site)

(2) The length of time following a disposal event before aquaculture activities could begin would be a site-specific variable depending on the site's size and configuration, the volume and character of the dredged material, and the possible use of dredged material dewatering and other volume-reducing techniques for efficient containment site management. A site without cross dikes will not be available to aquaculture during the active dewatering period. Otherwise, aquaculture and dewatering objectives are totally compatible.

b. Aquaculture Products. Aquaculture in containment sites could be designed to produce crops for commercial harvest or could be directed toward producing fish and shellfish stocks for release to augment depressed natural populations. Current aquaculture-for-release programs in California, Texas, the Pacific Northwest, Japan, and the Middle East use natural and artificial coastal ponds, lagoons, and embayments for their propagation programs. Similar programs could easily be undertaken in containment areas.

c. Site Characteristics. Containment sites exhibit a wide range of variability: location, size, construction, compatibility of aquaculture with disposal requirements, and a myriad of other site-specific physical and chemical features which make each containment area unique. Not all containment sites will be suitable for aquaculture, but a significant number have the proper combination of features to support aquaculture. Crucial to developing aquaculture as a secondary use of containment sites is the fact that aquaculture will be possible only if it is compatible with the disposal requirements and schedules imposed by the intended primary use of the site, i.e. dredged material disposal. Only when both the aquaculturist’s and the disposal agency’s requirements are met can the site be developed for aquaculture.

d. Site Acquisition and Permitting. Site development and pond management practices are expected to be similar to those presently used in commercial aquaculture operations. Major exceptions lie in the areas of site acquisition by entrepreneurs and permit-granting procedures. Existing easement agreements would have to be amended, requiring prospective aquaculturists to reach separate agreements with both the property owner and the CE. Representatives of commercial aquaculture enterprises claim that the current permitting process is so involved and complex that the growth of aquaculture in the United States is effectively thwarted. Having the CE involved in promoting aquaculture in addition to retaining its traditional role in the permitting process could possibly expedite the process in the future.

e. Use of Contaminated Sediment.

(1) Waterway and harbor sediments placed into containment sites are sometimes contaminated with elevated concentrations of heavy metals, pesticides, petroleum hydrocarbons, and PCBs. Inorganic contaminants such as metals are generally incorporated in sediment particles while organic contaminants such as petroleum hydrocarbons and PCBs are generally associated with organic material present in the sediments. Because of the way contaminants are retained within sediments, they are relatively unavailable to aquatic animals; those that are available are generally not concentrated by aquatic animals to levels much in excess of those found in the sediments.

(2) Laboratory experiments in which aquatic animals were exposed to sediments contaminated with various metals and organic contaminants have shown that the organics are more likely to be transferred from sediments to animals. Animals, such as certain marine worms that live and feed below the surface of the sediment, are more likely to accumulate organic compounds like PCBs than most shrimp or clams, which live or feed at or above the surface of the sediment. Higher levels of organic material in the sediment appear to reduce the biological availability of PCBs and other organic chemicals in sediments. There are some data to indicate that animals can accumulate lead and petroleum hydrocarbons from contaminated sediments, but the levels of these contaminants found in these animals are low in comparison to sediment levels, and there is no evidence that they are harmed by these low levels of contamination.

(3) Most studies generally focused on highly contaminated sediments and should be viewed as representing the “worst case.” Containment sites used for the disposal of dredged material with “some contaminants” need not be viewed as a major constraint to their use for aquaculture. Test procedures for determining whether a particular sediment will be a problem to a specific aquacultured species are available, fast, and inexpensive. Contaminant status is something to be aware of and considered during the planning process.

f. Economics. The economic and marketing requirements of commercial finfish and shrimp culture operations and those operations conceived for containment areas are very similar. The capital investment requirements of containment area aquaculture could be significantly less. Simplified land acquisition, reduced real estate costs, shared costs of dike construction and maintenance, and the possibilities of an expedited permitting process would all contribute to reducing capital requirements. Operating costs will depend on site- and species-specific characteristics and are difficult to describe in general terms, but no extraordinary additional costs have been identified.

g. Pond Construction and Management.

(1) Pond construction and modification for aquaculture would be site and species specific. If a containment site satisfied initial geotechnical and engineering requirements, constructing additional dikes, installing water control equipment, and other necessary modifications should follow the procedures employed in conventional operations. Cooperative efforts involving aquaculturists, U.S. Soil Conservation Service (SCS), and the CE are recommended for developing designs and specifying any modifications necessary for using containment areas for aquaculture.

(2) Health considerations, water quality, and species management techniques for containment site culture should be identical to current practices, although the effects of large amounts of fine sediment in the containment area ponds and the lack of experience in managing large-scale aquaculture operations pose questions that still need to be answered. Management procedures for large ponds have not been developed for many species simply because large ponds have not been generally available. With increased availability afforded by the widespread use of containment site acreage, appropriate techniques should evolve. Similarly, adequate water exchange, aeration, and harvest techniques should overcome many difficulties created by the presence of large amounts of fine sediments.

10-4. Feasibility.

a. Aquaculture in active dredged material containment areas appears to be a feasible, cost-effective, and compatible multiple use of containment sites. Existing technology can be- directly applied to the concept, making it practical with little additional research and development investment required. The needs of the local areas, interests of the involved parties, and technical constraints will determine which type of culture operation (commercial or stock augmentation) and which species will be most suitable for a given site. Aquaculture is generally perceived to be only applicable in the U.S. in warmer climates. However, aquaculture is practiced commercially in the Pacific Northwest, California, New England, Chesapeake Bay, and the Carolinas, as well as in Florida and in the Gulf Coast states. Although growth rates are generally slower in colder waters, the concept is still highly applicable.

b. The large successful industries centered on crayfish, salmon, catfish, trout, and bait minnows can provide both the technical expertise and the sources of stock needed for developing a profitable operation. The technology involved in freshwater fish culture is both well defined and compatible with culture plans envisioned for containment areas. Redfish, exotic and native shrimp, hybrid striped bass, bait shrimp, and minnows are the most promising species for marine/brackish water culture.

CHAPTER 11

PARKS AND RECREATION

11-1. General.

a. Potential recreational uses of dredged material disposal sites are practically unlimited. They range from projects as simplistic as fill for a recreation access road to projects as complex as the 4,500-acre Mission Bay development in San Diego, California, supporting both public and private commarcel and noncommercial recreation facilities.

b. Of all types of beneficial uses, recreation on dredged material containment sites is one of the most prevalent land uses in actual acres. It is not surprising to find many examples of such use since there is such a demand for recreational sites in urban areas where much dredging occurs. It requires sound, careful planning to accomplish; financial investments will vary from project to project and could be quite expensive on large complex sites. The nature of recreation sites with requirements of a lot of open space and light-weight structures is especially suited to the weak foundation conditions associated with fine-grained dredged material. Recreational land also is generally for public use, and high demand for public water-oriented recreation encourages the development of recreational land use projects on dredged material. Finally, legislation relating to wetlands, coastal zone management, and flood control is biased in favor of this type of use. The recreational land use of dredged material containment sites is one of the more promising and implementable beneficial uses of dredged material, but is heavily dependent on financial backing at the local level.

c. There are many factors that influence the potential use of dredged material disposal sites for recreational purposes. Important ones that must be considered include the local or regional demand and need for recreational facilities, the interest and capability of local sponsors to participate in development and operation, and available access. Local and regional planners, State Comprehensive Outdoor Recreation Plans, and public participation programs are all sources of information about public demands and needs. Local and regional planners are also good sources of information on potential project sponsors.

11-2. Case Studies.

a. East Potomac Park. A non-commercial recreational development at East Potomac Park in southwest Washington, D.C., is located astride the confluence of the Anacostia and Potomac Rivers. Disposal operations completed in 1912 created 329 acres from fine-grained clays and organic materials dredged from the Potomac main channel. By 1925 the park reached full recreational development, and since 1939 ownership and operation of the facility have been in the hands of the National Park Service. The site currently offers four nine-hole golf courses and a snack bar, driving range, and clubhouse. Other recreational facilities include a swimming pool, indoor and outdoor tennis courts, eight baseball fields, and fields for field hockey, football, and polo. Buildings on the site include the National Park Service offices, a maintenance building, a comfort station, and several other minor structures. Use of the park open space for recreation has increased to the extent that the conversion of a portion of golf course land to open space is being considered. The park serves a regional need for recreation of residents of the District of Columbia, Arlington County, and the City of Alexandria, Virginia, as well as for area commuters. In 1975, the North Atlantic Division placed the value of the park at $94 million.

b. Patriots Point. The Patriots Point Project, a 450-acre commercially oriented recreational site immediately across the Cooper River, 1 mile east of Charleston, South Carolina, was built on an old disposal site. The site, formerly known as Hog Island, was used for disposal of maintenance and new channel dredged material--primarily mixed sandy silt and clay--from 1956 to 1970; dikes were constructed of heavy clay. In the early 1970's, a quasi-state agency, designated the Patriots Point Development Authority, was established to plan and develop a recreational complex. The focal point of the development is a Naval and Maritime Museum with the aircraft carrier Yorktown, moored at the site in early 1976, as the principal attraction. The Authority’s master plan includes an 18-hole golf course, a 150-room motor inn with convention facilities, a 375-slip marina, and a 300-space recreational vehicle park. Long-range plans include construction of an oceanarium, aquatic theatre, amphitheater, restaurant, man-made lakes, and permanent mooring for at least three more classes of decommissioned naval ships as the vessels become available. A dike-top tour route around the site has been constructed. The project will ultimately attract 1.5 million visitors annually. Structures at the site will be supported on pilings due to the compressible nature of the fine-grained dredged sediments and underlying organic material. An overburden of sand will be added to provide suitable drainage and foundation conditions for light structures and parking areas. Topsoil, including some dredged material, will also be placed in portions of the site to encourage vegetative growth, particularly in designated buffer zones. Figure 11-1 depicts the master plan for Patriots Point.

c. Kalawa Recreational Area. A large marina, fishing pier, and water sports complex was built on sandy dredged material in the Columbia River at Kalawa, Washington (Figure 11-2). The area was armored with riprap to prevent current erosion. It also contains park areas, a heliport, a recreational center, and baseball fields.

d. North Central United States. Numerous recreation sites such as riverside picnic areas, water parks, marinas, and other river-related sites have been built on dredged material, both by the CE and by private sponsors along the Upper Mississippi River and its tributaries. In the Great Lakes, parks, marinas, fishing piers, and other recreation facilities have been built

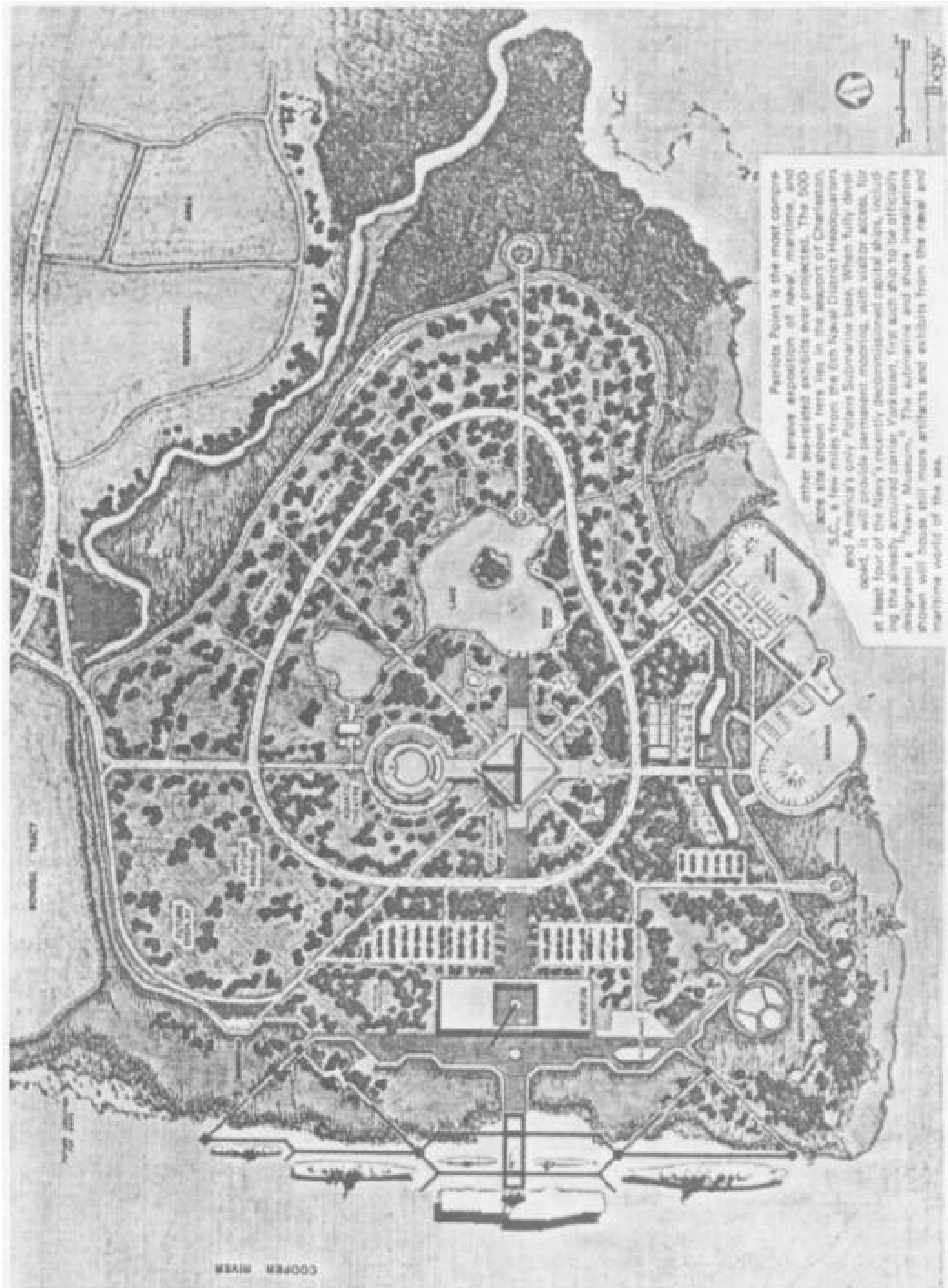


Figure 11-1. Master plan of Patriots Point Naval and Maritime Museum, Charleston, S.C. (item 15)

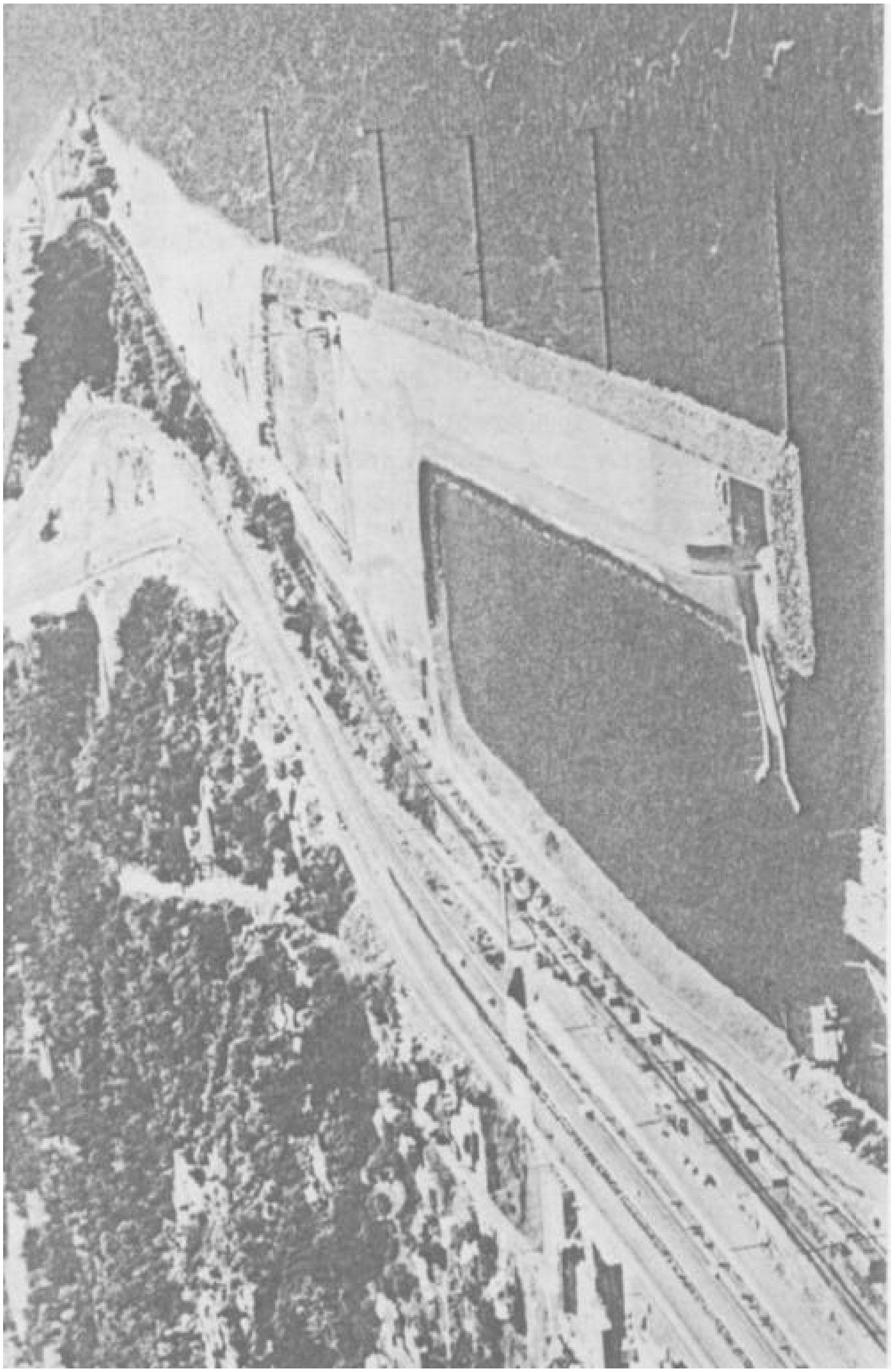


Figure 11-2. This riverside recreational area at Kalawa, Wash., was built on material dredged from the Columbia River

on dredged material in western Lake Erie, Lake St. Clair, Duluth Harbor, and a number of other urban areas.

e. Others. A total of 136 examples of recreational use of dredged material are listed in Appendix C.

11-3. Recreation Activities and Facilities.

a. Certain types of private recreation facilities, while they are on dredged material disposal sites, are normally provided by private enterprise. Although the CE does not participate in the provision of these types of facilities, they should be regarded as potential beneficial uses since they occur on disposal sites. These sites often provide cost-feasible and socially acceptable disposal alternatives. There are also many opportunities for providing recreation opportunities at disposal sites. Disposal sites in coastal and riverine areas have highly diverse recreation potential, especially for water-oriented activities. These sites are especially attractive for shoreline recreation development such as swimming beaches, boat launching ramps, and fishing piers. When areas are of sufficient size, campgrounds, marinas, outdoor sport facilities, and hiking and nature trail systems may be constructed. Recreation development potential of these areas is quite high when authority, funds, and land area are all of sufficient amounts, and the public interest is best served by such development. The types of activities and facilities that can be provided on dredged material sites are included in Table 11-1. Recreation planning and design criteria for specific recreation facilities are provided in EM 1110-2-400. While high site recreational use is generally dependent on facilities development, undeveloped disposal lands also attract a segment of the public for activities appropriate for those areas, such as nature study, primitive camping, hiking, hunting, and beach-combing. Provision for access to these areas is one of the minimal requirements. These undeveloped sites are also used as trails for off-road vehicular recreation.

b. Dredged material disposal islands are also used extensively for recreational purposes. They provide a base for such water-based activities as hunting, fishing, boating, waterskiing, swimming, and camping. In many river and estuarine systems, dredged material islands and beaches are the only available sandy beaches, and there is often danger of site use conflict between wildlife, especially nesting colonial birds and turtles, and humans. The recreation experience and enjoyment of the users can be affected by the development and design of the disposal sites and by the timing of disposal operations. Variations in size, proximity, and level of development of camping sites can provide a diversity of recreation experiences.

c. Development of facilities and vegetation on these islands should preserve the more primitive conditions of naturally occurring point or island bars. A study of recreation users on the Upper Mississippi River noted preferences for undeveloped islands composed of mostly open sand with some trees and grass; islands with riverine vegetation were not favored. Extensive vegetation of disposal islands is therefore not required nor desired for

Table 11-1

Types of Recreational Activities and Facilities Found on Dredged Material Disposal Sites

Activities	Required Facilities
Beach-combing	Beach
Bicycling	Trails or roads
Bird watching	Undeveloped natural areas
Boat launching	Ramps, parking area, marina
Camping	Campground
Dining	Restaurants and snack shops
Fishing	Water access
Hiking	Trails
Hunting	Undeveloped natural areas
Motorcross and dirt biking	Trails
Nature study	Undeveloped natural areas
Outdoor games	Athletic fields and playgrounds
Picnicking	Tables, trash receptacles
Sunbathing	Beach
Swimming	Beach
Viewing	Scenic overlook or observation tower

recreational use. The use of a given dredged material island or sandbar was influenced by the presence of sandy beach areas, adequate water depth for boats, and uncrowded conditions which gave users relative isolation from other campers.

d. Proper location of dredged material islands and access points can also reduce boating congestion in locks and navigation channels. Many boaters in the Upper Mississippi River survey noted that they used the locks only to reach their favorite disposal sites. Development of multiple launching points and/or the location of specifically designed disposal sites near population centers could eliminate some of the recreation blockages and the traffic congestion in navigation channels.

e. The recreation potential of both shoreline and island disposal areas can be enhanced by management of fish and wildlife habitat. Fish and wildlife habitat development can be an authorized purpose and secondary goal of navigation projects involving dredging. Wildlife enhancement and mitigation may also be required to offset habitat losses due to project construction. In such cases, lands are generally purchased or long-term easements obtained, and detailed habitat management plans developed and implemented. However, in a number of areas where dredging occurs, disposal sites are limited, and a well-developed long-range management plan is usually lacking for disposal sites. In these instances it may be more practical to manage for nongame species and nonconsumptive recreational use rather than the more traditional game management for sport hunting. A variety of songbirds and other small animals are appreciated by the public, and with proper habitat management (nest boxes, food and cover plantings, etc.), these species can be encouraged around picnic, camping, and other recreation areas.

f. When fishing is a recreational goal at a disposal site, some basic management techniques to maintain high populations and harvests of game fishes may be required by developing and maintaining ponded areas in-disposal sites. Spawning beds and water level manipulation to enhance reproduction, reefs, and piers to attract and concentrate fish, and a sound plan for dredged material disposal will contribute to a healthy sports fishery in a given area.

11-4. Recreation Carrying Capacity.

a. Proper design of recreation developments on dredged material disposal sites can ensure that recreation use does not exceed the recreation carrying capacity of the resource. Carrying capacity is the maximum potential level of use which avoids social overcrowding and resource overuse. A number of methods are available to estimate recreation carrying capacity of projects (item 79). Proper project design of structures, facilities, and access points decreases the likelihood of overuse or underuse. Overuse of recreational resources results in overcrowding of recreation users and degradation of the dredged material resource.

b. Sandbars, beaches, and other disposal sites can be strategically located to further disburse recreation use to areas able to support the use. Barriers and screens such as ditches, fences, and berms can be placed adjacent to environmentally sensitive areas and hazardous locations at disposal sites such as those where incremental dredging is still occurring and where recreation use is not desired. On such sites still in active use, serious consideration must be given to liability from accidental or purposeful human intrusion onto the active disposal portion of the site. The density concentrations of boating, boat fishing, and waterskiing can be affected in part by the number, location, and distribution of boat launching, docking, and servicing facilities built throughout an area. Providing multiple launching and docking facilities at disposal sites tends to reduce density concentrations and distribute recreation use more evenly.

CHAPTER 12

AGRICULTURE, HORTICULTURE, AND FORESTRY

12-1. General. Broad use of dredged material disposal sites has been made by the agriculture, forestry, and horticulture industries. Some disposal sites, especially in river systems, have provided livestock pastures. These pastures have not been developed in any way except by allowing natural grass colonization or by planting pasture grasses on them. Other uses involve actively incorporating dredged material into marginal soils (item 25). An attractive alternative for disposing of dredged sediments is to use these rich materials to amend marginal soils for agriculture, forestry, and horticulture purposes. Marginal soils are not intensively farmed because of inherent limitations such as poor drainage, unsuitable grain size, and poor physical and chemical conditions. They may also be of low productivity because of high water tables or frequency of flooding. Millions of acres of these marginal soils are located near waterways.

12-2. Agriculture. Item 81 notes several areas where there is currently extensive interest in the agricultural use of dredged material. For example, about 500 acres of the Old Daniel Island Disposal Site in South Carolina have been successfully truck farmed for the past 8 years, and other parts of the site are planted in soybeans, an agronomic crop. The Tulsa District has approximately 2,600 acres of dredged material containment sites leased for use as grazing land. When dredged material is free of nuisance weeds and has the proper balance of nutrients, it is similar to productive agricultural soils and can be beneficial for increasing crop production when incorporated or mixed. By the addition of dredged material, the physical and chemical characteristics of a marginal soil can be altered to such an extent that water and nutrients become more available for crop growth. In some cases, raising the elevation of the soil surface with a cover of dredged material may improve surface drainage and reduce flooding and therefore lengthen the growing season. Dredged material characteristics which influence plant growth and guidance for dredged material incorporation and cover use are discussed in this section.

a. Planning Considerations. Chemical and physical analyses of the dredged material, site locations, weed infestation potential, and possible salinity problems must be considered before deciding upon the suitability of a specific dredged material as a medium for agricultural purposes. Figure 12-1 demonstrates priority listing of these factors to be used when considering the feasibility of an agricultural use for dredged material at the containment site (item 75).

(1) Chemical analyses. Since dredging operations may take place in waterways containing industrial wastes and sediment runoff from agricultural areas, dredged material can contain heavy metals, oil and grease, high nutrient concentrations from fertilizer runoff, and other contaminants.

(a) Heavy metals. Heavy metal uptake by plants is dependent on a number of factors, primarily the form and concentration of metals in the rooting media, and the type and variety of plant. Research has shown that the heavy metal uptake by plants is normally much less than the heavy metal content of the rooting media (items 25 and 44). Table 12-1 shows the range in the concentration of heavy metal uptake by agronomic and common vegetable food crops grown under normal conditions and the suggested plant tolerance levels (item 25). The question as to whether or not to produce food or nonfood crops depends upon the chemical contaminants present in the dredged material. Agricultural service agencies and extension offices can assist with guidelines and answers to specific questions. While research has shown that relationships exist between the extractable heavy metals in the soil and the heavy metal uptake by certain plants (item 46), these data are important to dredged material applications upon soils if a food crop is to be grown, but are less

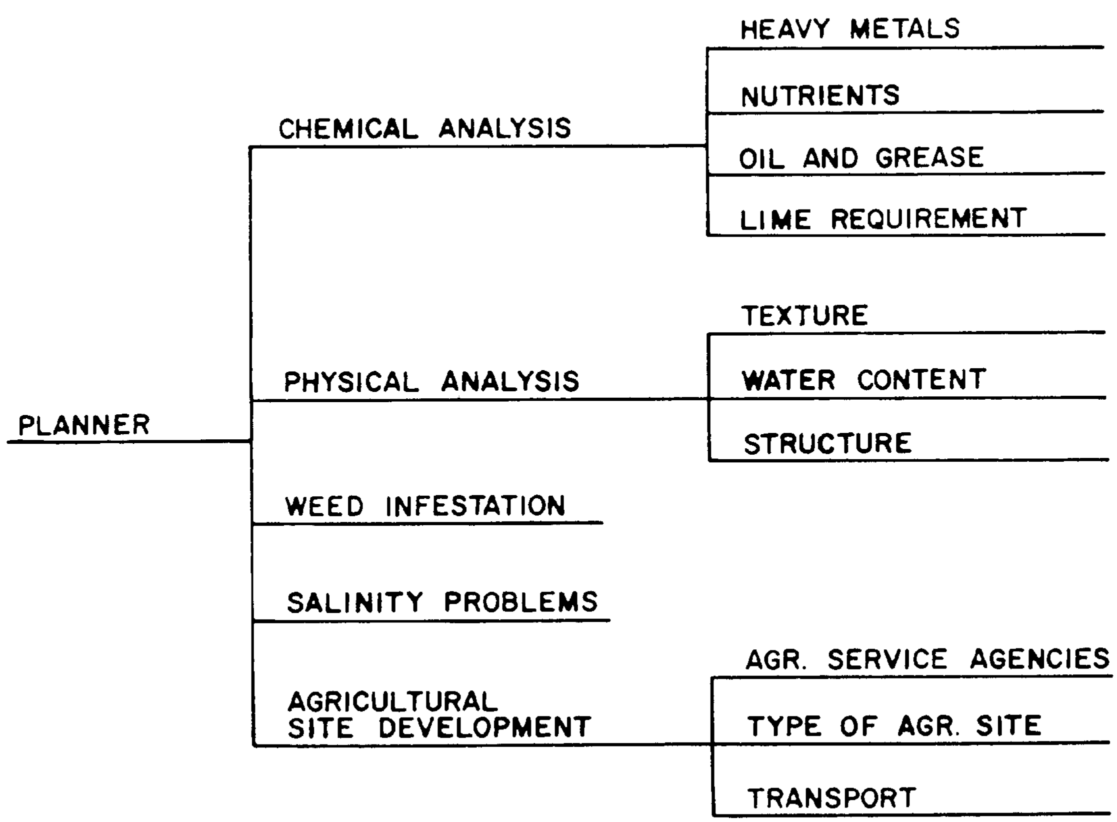


Figure 12-1. Decisional factors to be considered at the dredged material containment area before applying dredged material for agricultural purposes

important when nonfood crops are to be produced. An example of a nonfood crop is the growing of Christmas trees or pulpwood on dredged material containing concentrations of heavy metals too high for human or wildlife consumption (item 49). Another example is the uptake of minimal amounts of heavy metals in the heads of grain plants, making them a good food crop selection even if larger amounts of heavy metals are present; however, the heavy metals may concentrate in the leaves, making these grain crops less desirable when harvested as a forage.

(b) Nutrients. Nutrient analyses of dredged material should provide data to determine nutrient availability and to establish recommended fertilizer applications for vegetative production. The nutrient constituents of dredged material which require greatest attention are nitrogen, phosphorus, potassium, metallic metals, and organic compounds. Although medium- and fine-grained dredged material is normally high in nutrients available for plant uptake, the levels of these nutrients are usually not high enough to limit plant growth. However, nitrogen, which is usually in the ammonium form, will undergo nitrification rapidly in an aerobic soil. Nitrate is the readily available form of nitrogen for plant uptake or loss by surface runoff and leaching into ground water. Specific recommendations on rates of fertilizers can be obtained from the state Soil Testing Service or local agricultural extension agent, after soil tests have been conducted. A considerable portion of dredged material, especially in the Upper Mississippi River and some

Table 12-1

Average Range of Heavy Metal Uptake by Plants for Selected Food Crops* and Suggested Plant Tolerance Levels (item 25)

Element	Average Range ppm	Suggested Tolerance Level, ppm
Cadmium	0.05-0.20	4
Copper	3-40	150
Iron	20-300	850
Manganese	15-150	325
Nickel	0.01-1.0	4
Lead	0.1-5.0	10
Zinc	15-150	350
Boron	7-75	200
Chromium	0.1-0.5	2

* Corn, soybeans, tomatoes, beets, lettuce, peas, potatoes, melons, squash, alfalfa, clover, wheat, oat, barley, and pasture grasses.

coastal areas, is sterile, clean sand. In these cases, sites may never be suitable for agriculture, and will need major nutrient and soil amendment incorporation.

(c) Oil and grease. Research has shown that the oil and grease content of some dredged material is considerably higher than that of soil. However, depressed agricultural yields attributable to high oil and grease content have not been studied. Possible effects of high oil and grease content on soil properties or plant growth are an apparent slower wetting of the soil materials, a smothering effect on plant parts, and a tendency to restrict water uptake by the plants.

(d) Lime requirements. Lime requirements for dredged material vary, but if the pH of the material is below 6.5, it should be amended with ground agricultural limestone before being applied to marginal soil for agricultural production. Large amounts of sulfur in the dredged material will require heavy initial applications of lime to neutralize the acidity, as well as succeeding applications to maintain neutral conditions. A soil pH below 4.0 indicates the presence of free acids resulting from the accumulation of sulfate and nitrate ions; a pH below 5.5 suggests the presence of toxic quantities of exchangeable aluminum, iron, and manganese; and a pH from 7.8 to 8.2 may indicate an accumulation of the bicarbonate ion, and the uptake of elements will be detrimental to plant growth. Gupta et al (item 25) provides specific recommendations on rates of both fertilizer and lime to apply at various soil (dredged material) deficiency levels. A rule of thumb for lime requirements of high sulfur dredged material is to double the usual lime requirement.

(2) Physical analyses. The physical characteristics of dredged material can assist the CE in making critical judgments of the best use of dredged material to ensure against adverse impacts on agricultural lands. The texture and water content are essential tests to aid in characterization of dredged material deposits within a containment site.

(a) Texture. Textural classification helps to determine not only the nutrient-supplying ability of soil materials, but also the supply and exchange of water and air that are so important to plant life. Therefore, an important criterion is to adjust the texture of the final mixture of dredged material and marginal soil to approximate a loam soil (USDA classification). Using the USCS classification system, a dredged material of loam texture contains silts and clays whose liquid limit is less than 50. Mixing a fine-textured dredged material (silt and clay) with a coarse-textured marginal soil (sand) to the proportions of a loam would improve its physical and chemical characteristics for crop production. Sandy, coarse-grained dredged material is generally low in organic matter content, available nutrients, and heavy metal concentrations. Dredged material of this type may have potential as an amendment to heavy impermeable clay soils, improving structure and permeability. For beneficial surface applications without incorporation with existing soils, it would be preferable to apply dredged material of loam textures only. Sandy loams are generally preferred for vegetable root crops such as carrots, beets, potatoes, and peanuts, whereas loam to silt-loam soils are preferred for row crops, orchards, and small grains.

(b) Water content. When placing dredged material on agricultural lands, it is desirable to have the water content of the material within the plastic limit range. This will present fewer problems in handling, placing, and mixing. If dredged material is to be placed in slurry form, the lift thickness should be limited to 18 inches. This thickness of dredged material will usually dry within a 6-month period, depending upon dredged material texture, to the point where soil mixing and farming operations can begin.

(3) Weeds. Weed infestation is generally a serious problem in many dewatered, inactive, fine-grained dredged material containment areas. Prior to the transport of dewatered dredged material to an agricultural site, an extensive weed control effort may have to be initiated to avoid serious weed problems to the agricultural producer. For example, an application of herbicide or removal of the top 6-inch vegetation layer of the containment area with a bulldozer before the transport of dredged material to the agricultural site would temporarily control the weed problem. Transport of such material, unless it was only to the advantage of the CE to do so, would be at the expense of the agricultural producer.

(4) Salinity. If the dredged material is from a coastal or tidal region, special attention must be given to salinity because crops will not grow on highly saline soils, and few agronomic crops will grow in brackish soils. The electrical conductivity of a soil water extract gives an indication of the total concentration of soluble salts in the soil. The term “soluble salts” refers to the inorganic soil constituents that are soluble in water. Excess soluble salts not only limit the availability of water to plants but also restrict growth. Salt-tolerant plant species are available and research on salt-tolerant agriculture crops is under way, but none have been found to be economically productive to date. Techniques for treating dredged material with high salinity problems are available and should be completed before the material is transported to an agricultural site.

(5) Agricultural site selection. The distance and mode of transportation utilized for the movement of dredged material will determine the major costs of its application to agricultural lands. Thus, the agricultural site selected should be in reasonable proximity to the dredged material disposal site and adaptable to the long-range disposal needs of the CE.

(a) Agricultural service agencies. In most areas of the country, a variety of suitable locations of marginal soils can be found by contacting the local offices of the SCS and U.S. Forest Service, as well as the local Agricultural Extension Service. Soil classification and land use maps are available from these agencies, as is direct assistance in locating marginal soils suitable for amendment with dredged material.

(b) Type of agricultural site. The type of site determines whether it can be used for agriculture, i.e., a short-term or long-term disposal area. Short-term usage means 1 to 3 months' time for the transfer of dredged material from a containment site, and for the transport, spread, mix, and cultivation of the dredged material for seedbed preparation at the agricultural site. Long-term usage implies that the agricultural site can be used as an active disposal area over a long period of time (5 or 10 years). This would involve only a few acres of the agricultural site at any one time in applications of dredged material, so that the rest of the field could be planted in crops. A schematic of a long-term disposal area is shown in Figure 12-2, where various levels of dredged material are being used for different activities. Shallow-rooted crops such as grasses, small grains, soybeans, and vegetables can be cultivated in designated areas when dredged material is first applied (6- to 12-inch depth). However, as the application of dredged material is continued in specific areas of the field (3 feet or more in depth), deep-rooted crops such as corn, sorghum, cotton, alfalfa, and trees can be successfully cultivated.

(c) Transport. The accessibility to the dredged material containment site and the agricultural site determines project viability and mode of transport. The agricultural site may have limited access due to field roads, drainage ditches, and fence locations; therefore, access routes on a farm may require design and construction to facilitate the disposal and spreading of dredged material. If the application of dredged material is to be efficient and effective, scheduling of application should not interfere with normal farm operations. Access roads to the disposal site should circumvent the farmstead and avoid the location of poultry and livestock.

b. Agricultural Site Considerations. With an understanding of the characteristics of the dredged material at the various disposal sites, consideration should be given to the potential problems at the agricultural site. Factors which must be considered at the agricultural site are properties of the marginal soil, application depth of dredged material, land preparation needs, compaction, erosion potential, flood/drainage area, and seedbed preparation (item 75).

(1) Incorporation. The beneficial effects of incorporating dredged material into marginal soils are increased available water capacity, increased nutrient supply when fine-grained dredged material is mixed with coarse-grained marginal soils, and improved drainage when coarse-grained dredged material is mixed with fine-grained marginal soils (item 52).

(a) Marginal soil. Marginal soils are not used for production of crops due to low economic return. These soils can be unproductive pastures, abandoned fields, fields requiring excessive irrigation or drainage, or areas in various stages of degradation. These soils can be made productive for a variety of economic crops by incorporating dredged material of desirable grain sizes to bring these marginal soils to a loam soil classification.

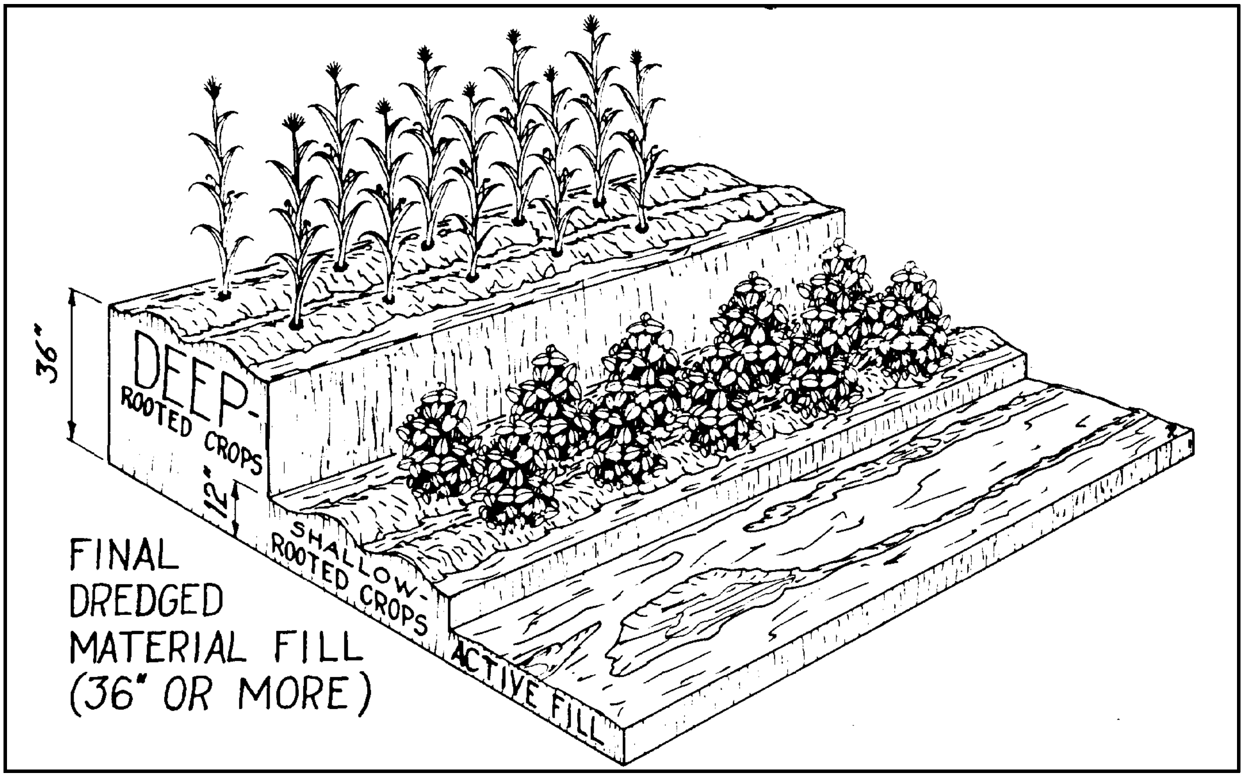


Figure 2-12. Long-term agricultural dredged material disposal site (item 75)

(b) Depth. Plant growth can be limited by root development; therefore, it is important to increase the depth of rooting media on marginal soils with applications of dredged material. To obtain an optimal mixture under normal field conditions, the depth of dredged material to be incorporated is limited to a 6-inch cover. At this depth, a 16-inch moldboard plow can furrow the 6 inches of dredged material to a depth of 12 inches using a tractor-plow combination. If incorporation of greater depths of dredged material is required, then special types of plows not common to normal farm operations must be used.

(c) Land preparation. Tillage operations prior to the application of dredged material may be useful to speed surface drying and eradicate weeds. The application of dry dredged material to level soil surfaces presents few problems when the soil surfaces are dry. If the agricultural site has poor drainage, the application of dredged material should be done after the area has had an opportunity to dry. Row drains can be constructed with a plow that cuts through low areas to provide drainage into field laterals. The addition of dredged material to slopes ranging from 5 to 10 percent may increase operational problems and the potential for erosion, as well as the sediment content in runoff water. If steep slopes (greater than 10 percent) are to be used, standard conservation practices should apply, possibly including terraces, grassed waterways, diversion channels, and supplemental practices such as contour farming, strip-cropping, and crop rotation (item 75).

(d) Compaction. The purpose of using dredged material is to improve the agricultural site; therefore, the application and spreading of the dredged material should not impair agricultural production by severely compacting the marginal soil. For example, soil compaction problems associated with the weight per axle load of large (25-ton) dump trucks may necessitate using smaller (9-ton) dump trucks which would reduce soil compaction but increase transportation costs by 25 percent.

(e) Seedbed preparation. The use of various types of tillage equipment is, to some extent, dependent on the type of crop to be produced. However, tillage operations such as plowing and harrowing are common to all types of seedbed preparation. Cultivation and planting of the newly incorporated mixtures should be accomplished as soon as possible because tillage will increase the infiltration of water and reduce surface runoff, therefore lowering the potential for erosion.

(2) Cover. When the area to be covered is too rocky, gravelly, or otherwise unsuitable for cultivation, additions or capping with dry dredged material to depths of 1 foot or more without incorporation into the existing site may be required to improve the area for agronomic production. When dredged material is to be used as a surface cover or cap, it is best that the texture approximate a loam soil for crop production (item 25).

(a) Depth. The depth of dry dredged material to be applied in increments as a surface cover or cap should be at least 3 feet to ensure good drainage and an adequate rooting medium. This depth of 3 feet or more can be achieved by additions of 6-inch layers if the agricultural site can be used as an active dredged material disposal site over a period of years.

(b) Drainage/flood. When the soil depth is increased by additions of dredged material, the depth to the water table increases and reduces wet spots in the field, thus extending the period available for farming operations. If the area is only briefly and intermittently flooded, additions of 3 feet or more of dredged material may completely eliminate the flooding problem. If it is flooded enough to have reduced soil conditions, it is a wetland and should not be farmed.

(c) Erosion. Slopes greater than 10 percent are not generally used for the application of dredged material because the establishment of a vegetative ground cover is more difficult. When the dredged material is to be placed on erodible slopes, it should be planted in grass cover immediately until the dredged material has stabilized. If the agricultural site is a terraced area, the terraces should be seeded in a permanent vegetation cover to prevent accelerated erosion. Flat or nearly level agricultural fields are the most satisfactory for dredged material application and farming operations.

(d) Seedbed preparation. When the marginal soil is to be buried with over 2-foot depths of dredged material, it should be leveled with a bulldozer and other tractor-plow or disk combinations used for seedbed preparation. Any application of dredged material will require standard seedbed preparations to level and till the site.

c. Crop selection. There are a number of agricultural, or food, crops which have been or may be grown on dredged material. These include pasture grasses; food grains such as rice, corn, wheat, oats, rye, barley, and millet; soybeans; sunflowers; truck crops; and cotton. Crop selection for food and forage use is dependent upon climate, culture, and regional markets. The varieties of agricultural crops typically selected for production in any given area can be obtained from county and local Agricultural Extension Services and the county Soil Conservation District offices.

12-3. Horticulture. Horticulture crops are generally considered vegetable, fruit, nut, and ornamental varieties of commercially grown plants. Dredged material applications on soils for vegetable production, orchards, and nurseries will not differ from the guidelines discussed under agricultural planning and site considerations. Discussion will be limited to special horticultural crops.

a. Vegetable Production. All commercially grown vegetable truck crops can be produced on dredged material amended soils. Vegetables grow best on sandy loam soils of good texture, drainage, and aeration. The best types of dredged material mixtures for such crops would be sandy silts or silty dredged material which can be incorporated into an existing sandy site, or sandy dredged material which can be incorporated into an existing silt or clay site. Clays in general are too heavy for good vegetable production, but they could be improved by applications of sandy material.

b. Orchards. Few fruit and nut crops are produced close to waterways and dredging sites, with the exception of pecan orchards. In general, pear/peach/apple orchards and other pome fruits grow best on hillsides and out of low bottomlands, and citrus orchards generally grow best away from the influence of salt-spray. Although no disposal sites have been planted as orchards, such application is probably feasible. However, additional applications of dredged material once trees are established would have to be limited to not more than 6 inches to prevent damage to root systems due to soil aeration changes.

c. Ornamental Plant Nurseries. Ornamental liner shrubs in nurseries are grown two ways: potted or set in the ground in a high-quality soil mixture. Either type requires horticultural soil mixes of loamy soil, sand, peat, and vermiculite. Dewatered dredged material could be applied as a part of the soil mix in areas where soil must be trucked into nursery sites at considerable expense. Most commercial nurseries make their own soil mixes, and may be amenable to use of good quality dredged material. The major disadvantage would be the limited quantities of material a nursery would require.

d. Sod Farms. Urban and suburban areas require large quantities of readily available grass sod for such uses as residential lawns, parks, golf courses, and rights-of-way. Unless sites are available near these high-population areas for sod production, sod must be trucked into the area for sale by retail nurseries and shops. Marginal soils near urban centers could be brought into grass sod production through applications of dredged material. Since grass sod is less exacting in its growth requirements than most food crops, the type of dredged material used is not as critical. However, the material should be a loamy or silty sand substrate, if possible, to ensure best grass growth.

e. Christmas Tree Farms. Another specialized use of dredged material is the cultivation of Christmas trees on disposal sites (item 75). This has already been carried out successfully in the Baltimore District. Since Christmas trees require 5 to 8 years to reach marketable size, the disposal site or compartment on larger disposal sites is generally unavailable for such beneficial use. This will limit the feasibility of this option in most waterways where dredging occurs. If dewatered material is trucked (at sponsor expense) to a marginal soil site, then planted with trees, this beneficial use option would be more acceptable.

12-4. Forestry.

a. For a number of years, the timber industry has been working with tree genetics to produce faster growing, stronger trees, and with reclamation of disturbed eroding sites using trees, primarily pines. However, some hardwoods and black walnut have been tested in the northcentral United States, and numerous cottonwood, sycamore, and eucalyptus plantations for paper production have been planted in the southern United States. The improvement of marginal timber land with applications of dredged material would be received with interest and enthusiasm from foresters who have the problem of trying to produce timber on poor soil. There are several rapidly growing pulpwood species that may be grown in large disposal sites with several compartments once the compartments are nearing completion. Dewatered dredged material trucked to marginal land or abandoned disposal sites would be the sites most appropriate for timber production.

b. The same physical and chemical soil properties discussed under agricultural considerations would apply to forestry, except that trees could be grown safely on dredged material with higher contaminant levels than could food crops. The tolerance level of each timber crop for heavy metals and other contaminants and the physical characteristics of the material would be forestry limiting factors.

c. Since land would be tied up in tree production after planting for 10 to 30 years, the primary disadvantage of this beneficial use would be loss of disposal sites. An advantage would be use of moderately contaminated dredged material not suitable for many other beneficial uses. Dredged material trucked into a site could be spread with heavy equipment as deeply as desired by the forester since tree roots penetrate several feet into the substrate. Large quantities of dredged material could be disposed of on marginal sites in this manner, and made productive.

d. Commercial tree species that would be suitable for timber production on dredged material would be eastern cottonwood, American sycamore, eucalyptus, green ash, water oak, and sweet gum on periodically flooded (limited flooding) sites. These species would also have a shorter rotational requirement of 5 to 15 years. Long-leaf pine, slash pine, loblolly pine, black walnut, white ash, pecan, and several oak and hickory species would grow best on upland sites amended by dredged material applications.

CHAPTER 13

STRIP MINE RECLAMATION AND SOLID WASTE LANDFILL

13-1. General. Two beneficial uses of dredged material that are still fairly new concepts have proven to be feasible in laboratory, field, and District tests (items 4 and 75). These are the reclamation of abandoned strip mine sites that are too acidic for standard reclamation practices, and the capping of solid waste landfills (item 75). Both uses would require large quantities of dewatered dredged material that could be moderately contaminated and still be acceptable. Both uses would ultimately provide nonconsumptive vegetative cover to unsightly areas, and the areas could be further reclaimed for minimal-use recreation sites and/or wildlife habitat. Item 75 provides excellent discussion of both types of beneficial uses. The techniques discussed in this chapter also apply to pyrite soil reclamation, gravel pits, and rock quarries. St. Paul District has reclaimed an abandoned gravel pit, and Portland District has reclaimed a rock quarry using these techniques.

13-2. Strip Mine Reclamation. Various techniques have been developed to control acid mine drainage from surface mine spoils. The primary purpose of these techniques is to reduce air and water contact with the acid-generating mine spoils. Methods which accomplish this are reducing slopes, thereby lowering runoff velocities and erosion, and establishing plants on the mine spoils. A balance must be struck between slope reduction and increased infiltration capacity. Attempts to establish vegetative cover on highly acidic mine spoils have usually resulted in low survival rates. The lack of a vegetative cover on mine spoils will result in erosion and further exposure of acid-generating pyrites to air and water (item 75). In order to reduce adverse effects of mine spoils, placement of a topsoil or topsoil substitute suitable for vegetative growth such as dredged material is recommended. Application of dredged material to surface mine spoils will provide a cover that will reduce the infiltration of water and the diffusion of air to the pyrite material, and provide a suitable growing medium for vegetation. Planning must be coordinated with the landowner and, if the mine is an active surface mine, the mining operator. Before reclamation activities can commence, State reclamation laws which include the final grade of the area, cover requirements, and vegetation requirements must be assessed. Assistance for various aspects of surface mine reclamation can be obtained from state reclamation departments, county agricultural extension offices, the SCS, and the U.S. Office of Surface Mining.

a. Dredged Material Requirements. Dewatered dredged material can be used for surface mine reclamation in much the same way as topsoil or agricultural soil. If construction on the site is considered as the final land use for the reclaimed mining area, tests for consolidation, shear strength, and permeability should be performed on the dredged material as well as the mine spoil. Fractions of dredged material having different grain sizes can be mixed to provide a surface with desirable physical and engineering properties.

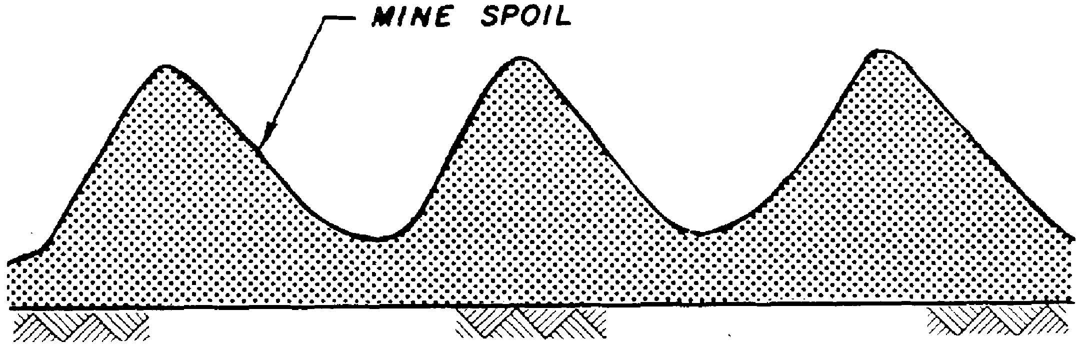
Almost any desired soil property can be obtained by dewatering, mixing, and compacting dredged material (item 4). Fine-grained or sandy silt dredged material can be used as a cover on mine spoils for the establishment of vegetation. Dewatered dredged material having a loam texture is the most desirable for best vegetation growth. The dredged material should be tested for pH, organic content, and soluble salts. It should have a nearly neutral (6.0 to 7.5) pH, a minimum organic content of 1.5 percent by weight, and a low amount of soluble salts (500 ppm or less) to allow optimum plant growth.

b. Site Preparation and Dredged Material Placement. The amount and method of site preparation needed at surface mines are dependent on the topography, the method of mining performed (area, contour, open pit, etc.), and the final land use. Site preparation consists chiefly of regrading the surface mine to a configuration that will accommodate a dredged material cover at a desired thickness and slope to support vegetation. The two principal surface mining techniques are area and contour mining. The potential for ground water percolation and contamination should be determined for both the mine spoil and the dredged material.

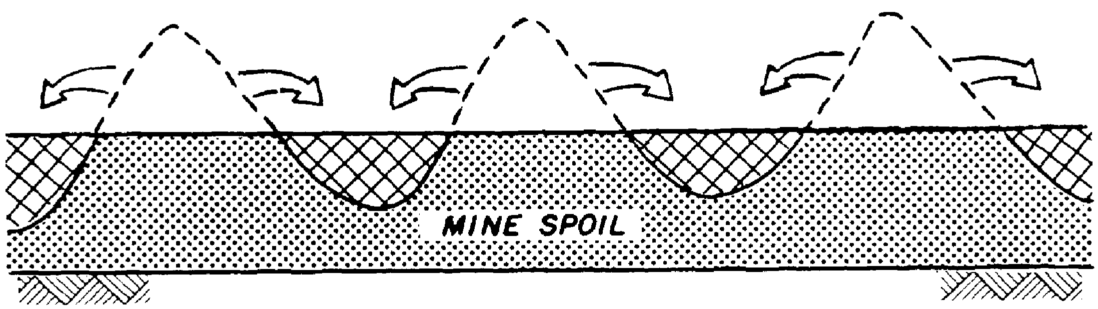
(1) Area mining reclamation.

(a) The area mining method produces the characteristic topography of a series of parallel ridges or piles of mine spoil. Site preparation consists of leveling mine spoil ridges or piles to a width specified by law and/or final land use. Leveling or “striking off” mine spoil ridges is accomplished by bulldozing the ridges into the valleys between ridges. The mine spoil piles should be leveled to a topography where conventional earthmoving equipment can spread dewatered dredged material to a desired thickness (Figure 13-1). This method of leveling was field tested by the Chicago District at Ottawa, Illinois. The mining site was leveled, capped with dewatered material, mixed, soil amendments added, and planted in a grass mixture. The site established vegetative cover rapidly, and is a very successful site (item 63). It has still maintained good vegetation cover 8 years after planting.

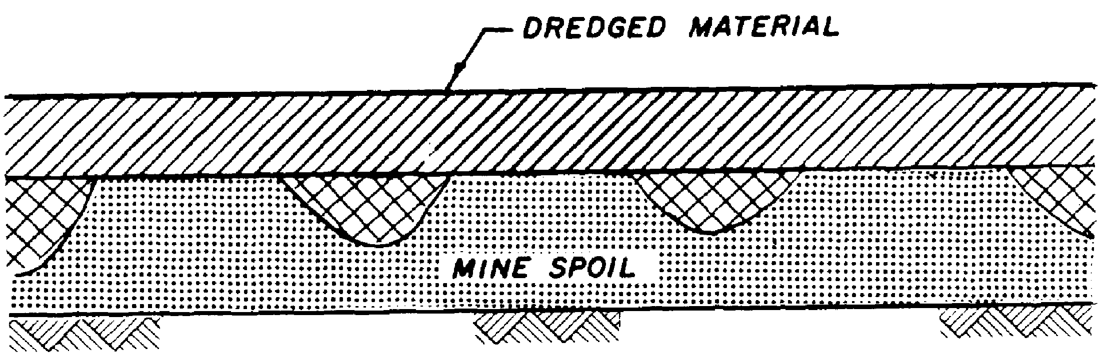
(b) An alternate concept of reclaiming area mines is the use of slurried dredged material. This method to date has not been field tested, but appears promising. It consists of hydraulically pumping dredged material in a pipeline onto a prepared area mine. This form of reclamation is only feasible for area mines located within pumping distance of an active dredging operation or rehandling basin. Preparation of the site consists of grading mine spoils to a fairly uniform level and constructing dikes around the area to contain the slurried dredged material. Because of the slurry’s high water content, it must be pumped in lifts and allowed to dewater before adding the next lift. The depth of each lift is dependent upon the final land use and time constraints (item 57). If the area is to be used for foundation material to support lightweight structures, the lifts of slurried dredged material should be limited to about 36 inches so that drying will be enhanced (item 52). The dredged material should be allowed to dry to a moisture content near its



a. Prereclamation



b. Grading the mine spoil



c. Application of dredged material

Figure 13-1. Schematic diagram showing operational techniques used to reclaim a surface mine spoil with dredged material plastic limit before adding the next lift (item 57). If the area being reclaimed is not planned to support structures and is mainly being reclaimed for recreation or vegetation establishment, the depth of each lift can be increased and the amount of time between lifts can be shortened.

(2) Contour mined land reclamation.

(a) The reclamation of contour mines is more difficult due to the hilly terrain in areas where this type of mining occurs. This technique of mining requires removal of the overburden by starting at the outcrop of the coal seam and proceeding along the contour around the hillside. The highwall is located on the uphill side, while a rim and steep downslope are covered by the spoil material cast down the hillside. Being above the grade of local drainage, water from the pits flows directly into natural waterways. Reclamation of contour mines involves backfilling and terracing the disturbed land to the approximate original contour or to a contour compatible with the surrounding terrain. This requires placing dredged material into strip pits and over the mine spoil which was cast downhill (Figure 13-2).

(b) The choice of which regrading technique to use for reclamation depends on many variables, including final land use, terrain, amount of dredged material, and state and Federal reclamation requirements. Concepts for using dredged material on contour mine backfill are shown in Figures 13-2, 13-3, and 13-4. The use of dredged material to reclaim the mine to the original ground surface level and contour is demonstrated in Figure 13-2. The mine spoil on the downslope is also covered with dredged material to provide a vegetative media. Figure 13-3 shows the use of the Georgia V-ditch technique which does not fill to the original soil surface but leaves a highwall and fill section to be leveled to support vegetative as well as agronomic production. The slope reduction technique, as shown in Figure 13-4, permits stockpiling of dewatered dredged material before final grading to original slopes and contours.

c. Vegetation Establishment.

(1) Establishment of a quick vegetative cover is important at reclamation sites for it is one of the most effective erosion control methods (item 63). It must be known whether the area is ultimately to be used for farming, grazing, construction, temporary soil stabilization, restoration for aesthetics, or other purposes. When selecting vegetation, plant species should be chosen that will be able to adapt to dredged material conditions, such as low pH, high moisture, grain-size distribution, and fertility level. The species selected should be adaptable to the climatic conditions (sunlight exposure, temperature, wind exposure, rainfall) found at the site. It is best to choose vegetation native to the area which can be easily propagated. A species mixture should be planted to ensure successful establishment of a vegetative cover (item 63).

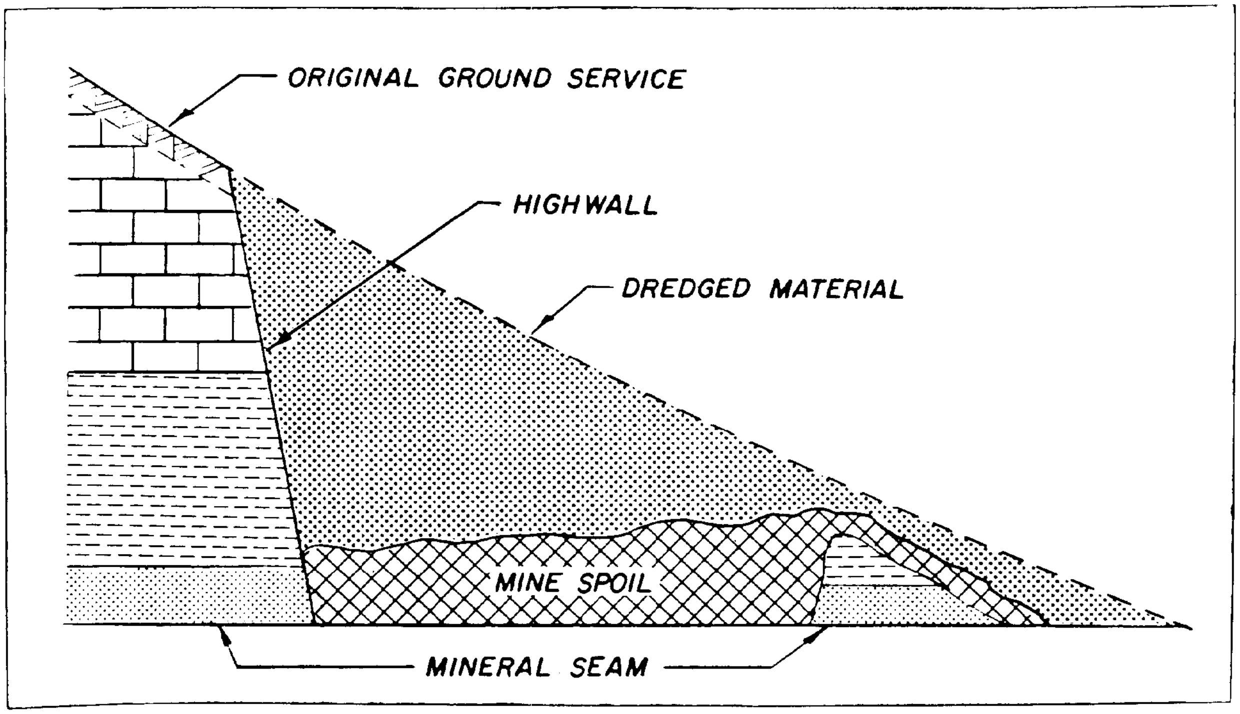


Figure 13-2. Gross-sectional view of contour backfill technique (itme 75)

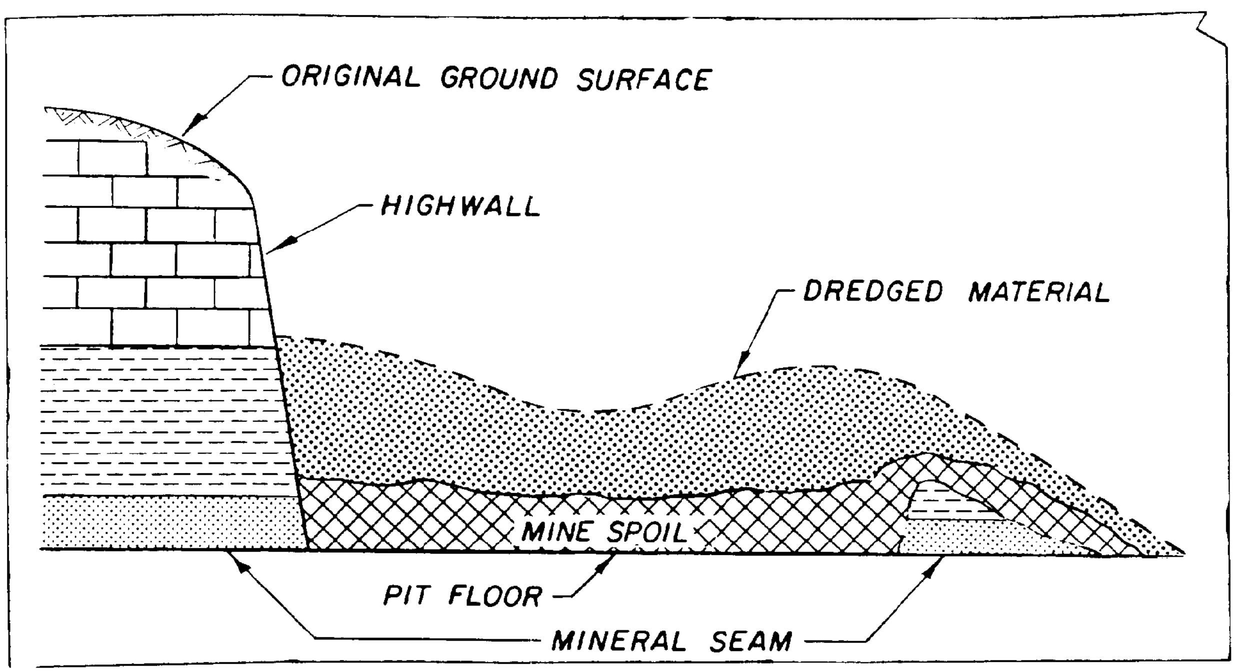


Figure 13-3. Gross-sectional view of the Georgia V-ditch backfill technique (item 75)

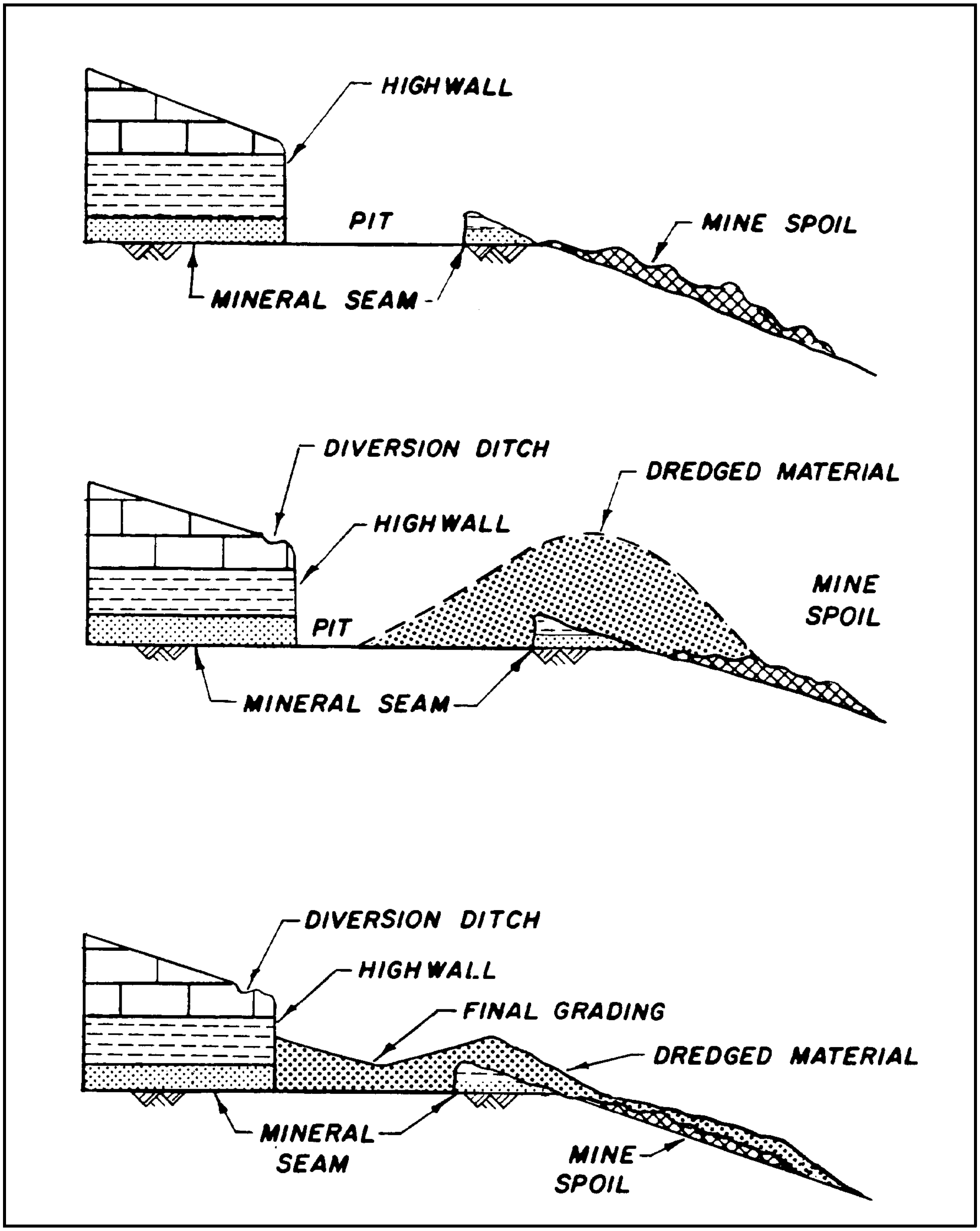


Figure 13-4. Schematic of slope reduction technique (item 75)

(2) It is desirable to roughen or cultivate the dredged material surface before seeding in order to reduce the velocity of rainfall runoff and increase water infiltration to seedbed depth. The surface of the dredged material should not be compacted because this impedes seedling emergence. Common methods for preparing the surface of the dredged material are scarification, tracking, and contour benching or plowing using disks, harrows, and tractors. Tracking grooves made by the cleats of a tractor should run parallel to the contour. Contour benching is performed on long slopes to build terraces to reduce the velocity of rainfall runoff (item 75). Terracing is performed with a bulldozer running parallel to the contour and allowing the soil to dribble off the edge of the blade. Furrowing of a terrace is performed by repeated plowing parallel to the contour. Other methods for planting such sites are available in items 16 and 32. Dredged material should not be placed on a slope that is in a frozen or muddy condition or when the subgrade is excessively wet or in a condition that may be detrimental to proper grading and the proposed seeding. Hydromulching or mechanical mulching on new cuts, revetments, dikes, and terraces is also usually required to prevent erosion.

d. Site Selection. Mining sites that would be suitable for dredged material disposal for reclamation purposes must meet certain criteria. The mined areas should be assessed for transportation capabilities as well as qualitative considerations such as social and environmental concerns. Field investigations of potential sites should include such general factors of the site as geology, ground water, effluent standards, ambient water quality, land costs, drainage, surrounding land use, and vegetation of adjacent lands. Permission for site use must also be obtained. Transportation costs are a major consideration, and are generally at sponsor expense. For this reason, mines that are near disposal sites and/or suitable transportation systems are probably the only ones feasible for consideration.

13-3. Solid Waste Landfills. Governmental agencies responsible for the management of solid waste are experiencing difficulties in obtaining suitable sites on which to operate environmentally sound solid waste disposal operations. A major portion of the solid waste generated in this country is ultimately placed on land in sanitary landfills. The location of a sanitary landfill is often constrained by the cover material requirements and availability and the site characteristics related to potential adverse environmental impact. Item 3 reports that dredged material can satisfactorily perform the functions of a cover material, thereby making it possible to locate sanitary landfills at sites previously considered unsuitable due to a lack of native cover soil. St. Paul and Mobile Districts have both used clean dredged material as caps for urban landfills. This section is intended to aid planners in determining the suitability of dredged material for productive use in solid waste management schemes and to provide guidance for development of possible landfill projects (items 3 and 75).

a. Dredged Material Characteristics. The potential uses for dewatered dredged material in a sanitary landfilling operation are as a material for covers, liners, gas vents, leachate drains, and gas barriers. Chapter 2 presented a discussion of physical and chemical characteristics to be considered when using dredged material in a land improvement project. Some dredged material grain-size distributions are generally more suitable than others.

(1) Cover. The solid waste in a sanitary landfill is covered daily with at least 6 inches of material to prevent an unsightly appearance, control vectors at the site, prevent internal fires, and control surface water infiltration. Landfills with two or more lifts must have intermediate covers 12 inches deep between lifts. The intermediate cover must fulfill all functions of a daily cover for up to 12 months and must be trafficable to assist vehicle support and movement. Dredged material characteristics of a desirable cover material are easy workability, moderate cohesion, and significant strength. A mixture of sand, silt, and clay has been shown to be a suitable cover material; if a gravel is fairly well graded with 10 to 15 percent sand and 5 percent or more fines, it can make an excellent cover. The only types of dredged material eliminated for use as cover are highly organic materials and peat. Due to the difficulty in handling, dredged material should not be used in the slurry state. On the other hand, the use of dewatered dredged material as cover is operationally feasible because the material can be easily hauled, spread, and compacted by conventional earth-moving equipment.

(2) Liners and barriers. Barriers and liners serve the same purpose, i.e., to prevent the migration (lateral and vertical) of leachate water or decomposition gases. The suitability of the dredged material for this use is determined by the permeability of the material. Dredged material with classifications of CL or CH is likely to be suitable for use in constructing a liner or barrier. Attempts should be made to keep these barriers and liners saturated to prevent cracking and to keep pore spaces filled with water to prevent gas leaks.

(3) Gas vents and leachate drains. Gas vents are used to direct the flow of gas to the atmosphere where it is harmlessly dissipated, and leachate drainage layers are used to intercept leachate and drain it to an area where it can be collected for treatment or recirculation (item 3). The controlled ventilation of gas requires that the vent be more pervious than the surrounding soil, and a leachate drain must also be very pervious so that leachate will be drained quickly away from the solid waste. To be suitable for venting gas or draining leachate, the dredged material must consist of sand or gravel with little or no fines and must be much more pervious than the soils at the site.

b. Site Considerations.

(1) Site selection. The selection of the solid waste disposal site will be the decision of the governing sanitary district. Site suitability and site management options will be evaluated by the sanitary district. The offer of dredged material to these districts allows them to consider sites initially screened out due to the lack of natural soil cover. It should be remembered

that in this beneficial use, the CE is simply providing a useful material to a sanitary district; therefore, site selection and construction and operation of the landfill are not the responsibility of the CE.

(2) Preliminary dredged material data collection. The dredged material source (dredging operation or containment area) should be defined in terms of location and quantity. Critical dredged material characteristics should be determined by examining physical and engineering characteristics and settling properties and by noting any evidence of contaminants. The available dredged material should be viewed in terms of suitability for sanitary landfill use, i.e., as covers, liners, barriers, vents, and drains. The dredging area should be assessed for available transport modes.

(3) Transport systems. For dredged material uses in solid waste management to be economically attractive, the landfill site must be within a reasonable distance of the dredged material supply. Not more than 50 miles is recommended in order to keep the unit cost of shipment down. Truck haul is the only mode of transport recommended because of its convenience, feasibility of operation, and ease of fitting into landfilling schemes (item 40).

(4) Economics. The success of any attempt to use dredged material in solid waste management will be dependent upon the economic feasibility of the project for each of the agencies concerned. Since each operation involving the use of dredged material in solid waste management is unique, economic feasibility is evaluated on a case-by-case basis. There should be a net benefit to all agencies involved.

CHAPTER 14

MULTIPURPOSE USES AND OTHER LAND USE CONCEPTS

14-1. General. With careful engineering design, construction, long-term coordination and planning, and proper implementation of operational and maintenance procedures, a disposal site having combinations of uses may be developed. This multipurpose use of disposal sites is strongly encouraged. A park and recreational development built over an existing solid waste landfill using dredged material as a cap is an example of how several of the beneficial uses discussed in the preceding sections can be lumped into a multipurpose project. There are a number of actual and planned examples of multipurpose sites. Often, multipurpose objectives do not involve substantial cost increases to the dredging project when plans are made in the initial phases of design and construction. Frequently, recreational use and wildlife and fish habitat can be developed simultaneously on a disposal site. Potential problems with development of multipurpose projects are usually related to conflicting user groups of the proposed disposal/development site. Careful selection of compatible potential users can avoid situations where the projected uses conflict.

14-2. Case Studies.

a. One example which demonstrates what can be accomplished when poor-grade dredged material is placed in conjunction with higher quality material to produce a multipurpose site is Aquatic Park in Toronto, Ontario, Canada. Along the shoreline, numerous commercial, transportation, and recreational sites have been created by the combined use of landfill and dredged material. Aquatic Park, under development by the Toronto Harbour Commissioners, is an excellent example of how the form of the land created can enhance the number and quality of productive uses. Construction rubble was used to create an approximately 3-mile-long headland running at an oblique angle to the natural shoreline. The headland is essentially linear but has numerous indentations in its shoreline dike. Dredged material was placed in the water behind the rubble dike where protection is afforded from wave and tidal action and associated erosion. The dredged material was placed to form contours for the development of lagoons and lakes along and behind the shoreline. The resultant configuration of the headland resembles natural landforms in the area. The length of shoreline- is many times the length that would have resulted from a conventionally shaped disposal area; thus, opportunity for shoreline utilization has been increased. Figure 14-1 shows Aquatic Park during dredged material placement in early stages of development.

b. Another very interesting and highly successful case study is Pointe Mouillee in western Lake Erie, Michigan (item 42) (Figure 14-2). Pointe Mouillee has been under development by the Detroit District for over 10 years. All engineering operations on the island portion and dikes were completed in 1983. The marsh phase of site development, including construction of

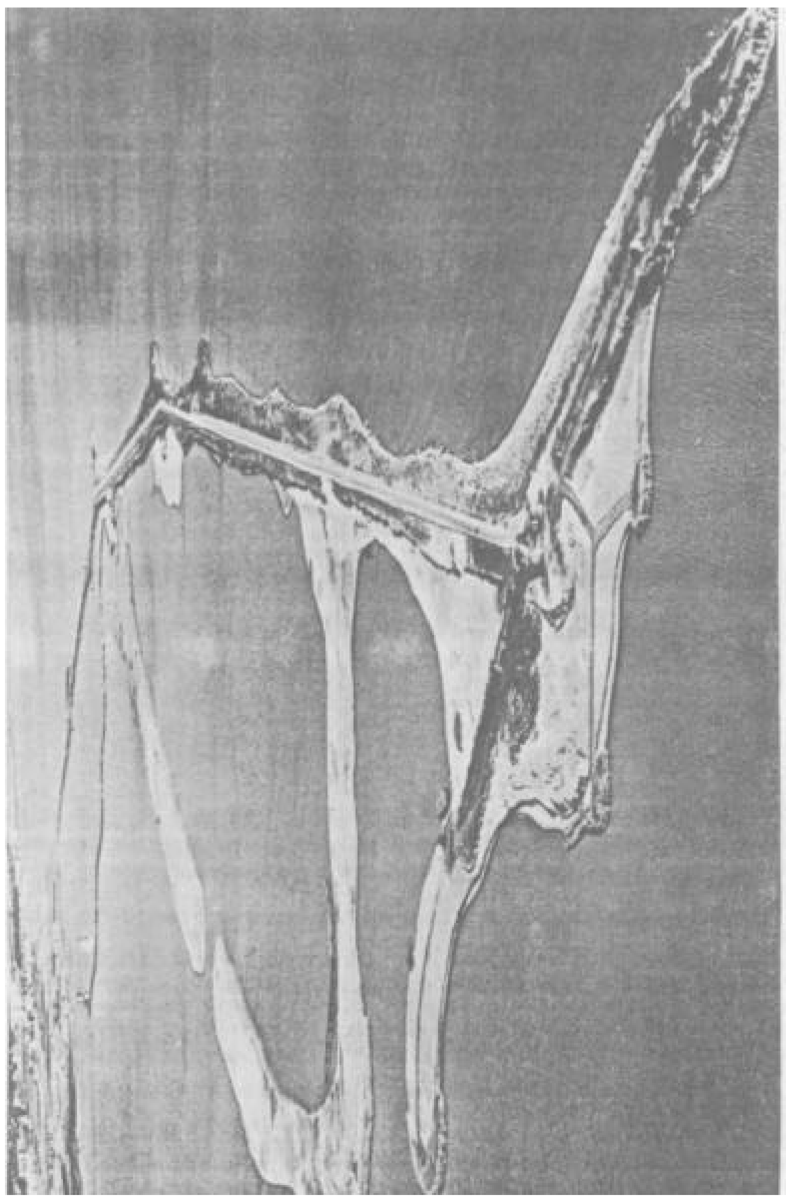


Figure 14-1. Dredged material placement at Aquatic Park, Toronto, Ontario, Canada

Figure 14-2. Pointe Mouillee, in western Lake Erie, is a CDF for contaminated dredged material that also serves as a multipurpose beneficial use site

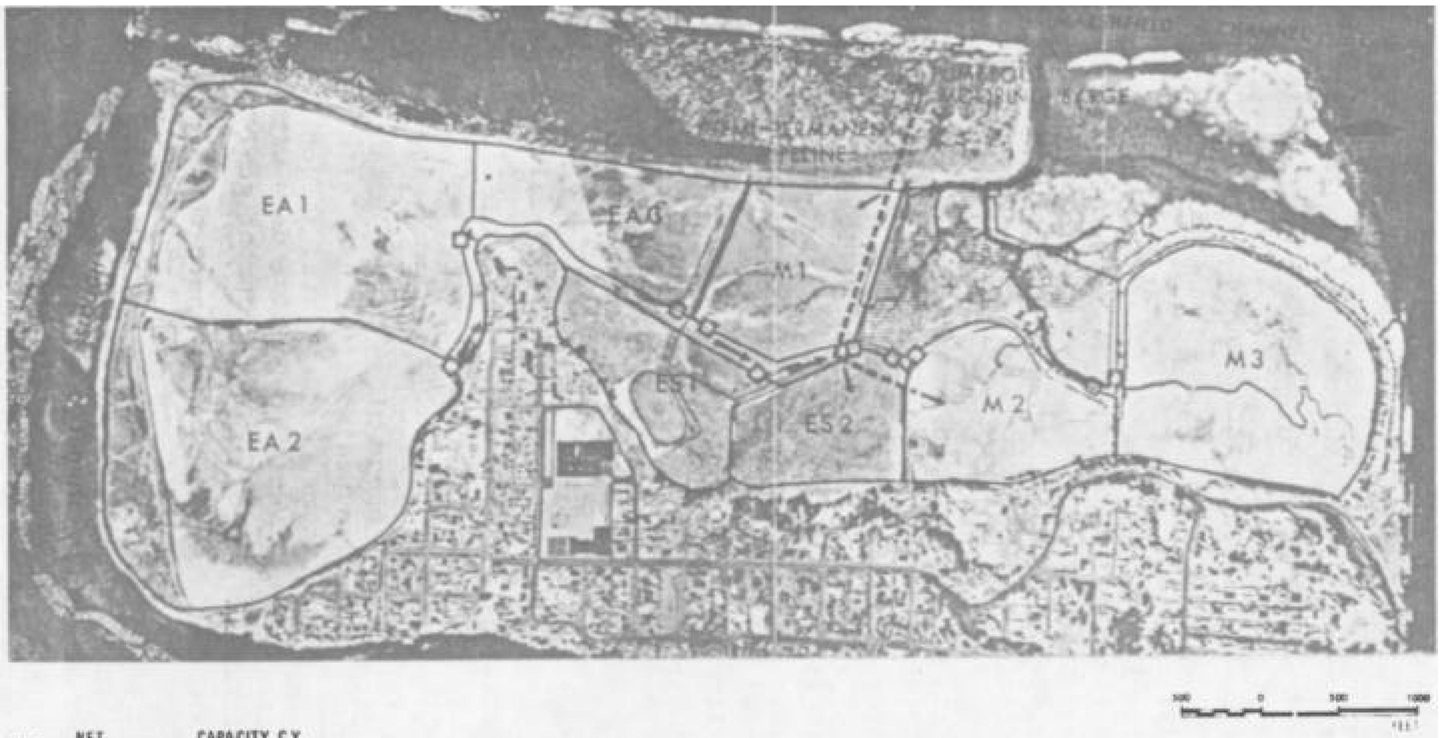
freshwater marshes, marinas, visitor center, public walks and areas, and fishing facilities, has just begun. The existing marsh inside the installed floodgates is progressing naturally, nourished by sediments trapped by channeling part of the Rouge and Detroit Rivers through the marsh. The nesting islands built of dredged material are covered with tall vegetation, and the fringes are being used by nesting waterfowl. Portions of the shoreline have been planted in grain fields for wildlife. Many of the barrier island dike compartments have been filled with dredged material to capacity, and they are colonizing naturally with locally occurring plant species. The island is scheduled to be planted with perennial grasses and forbs to create nesting and grazing meadows. Capping the dredged material with clean soil is also being considered (item 42). The dikes of the island have had waterbird use for loafing and feeding since construction began, primarily by gull species. This follows the expected pattern for construction in Lake Erie noted in the 1970s in which virtually every new dredged material site was colonized by nesting seabirds if the site consisted of suitable habitat (item 73). A management plan for the site was drafted in 1980-81 and is being followed carefully. This site is only one of two in the United States in which a CE District has applied and received permission to use Section 150 funds of the Water Resources Development Act (P.L. 94-587) for wetlands development, and up to $400,000 per dredging project has been earmarked for habitat development of Pointe Mouillee (item 59). This site is multipurpose, providing wetlands, upland, island, and aquatic habitat development; fishing, hunting, boating, recreation; ice fishing; nature trails; marina; visitor center; bird watching; and jogging and hiking.

c. A third example of a multipurpose disposal site is being developed in Coss Bay, Oregon, where a large containment site with eight compartments and extensive cross dikes is being filled and dewatered incrementally. The site will ultimately be developed for port, industrial, residential, and urban uses by the local sponsor, and parts of the site are scheduled for agricultural crops (Figure 14-3).

d. Some of the beneficial use examples given in other chapters of this EM that have actual multipurpose use include Gaillard Island at Mobile, Alabama; the aquaculture project at Freeport, Texas; all of the examples in Chapters 11 and 15; and a number of island habitat development sites where recreation and boating are also prime uses.

14-3. Other Land Use Concepts. Dredged material beneficial uses described and discussed in this EM are all highly productive, environmentally and economically acceptable alternatives to standard disposal practices. Dredged material has been shown in numerous cases to be a valuable resource with comparable properties of any saturated (or dewatered) soil. A few uses that may be considered beneficial did not merit separate chapters, but will be discussed here for completeness of this manual.

a. Erosion Gully Fill. Large quantities of dredged material could be disposed of within the numerous gullies formed from poor soil conservation



UNIT	NET AREA, AC.	CAPACITY, C.Y. SHORT RANGE	CAPACITY, C.Y. LONG RANGE
EA1	74.2	550,000	550,000
EA2	61.9	425,000	425,000
EA3	24.8	150,000	150,000
ES1	16.9	225,000	225,000
ES2	16.9	225,000	225,000
M1	25.9	875,000	875,000
M2	22.5	750,000	750,000
M3	49.5	1,676,000	1,675,000

Ultimate Uses: Industrial, Residential, Agricultural

KEY

RETURN FLOW STRUCTURE

RETURN FLOW

RETENTION BASIN

B-W SITE CLASSIFICATION

AREAS 16-17 B & 18-W

EASTSIDE AIRPORT
EASTSIDE SCHOOL
MARSHFIELD

Figure 14-3. Coos Bay, Oregon, disposal areas that will ultimately be used for industrial, residential, and agricultural purposes practices in both rural agricultural and urban construction areas. Such gullies are unsightly and unproductive and, generally, attempts to cover them with vegetation such as kudzu, rather than to reclaim them, are made. Since few of these hill sites occur within reach of hydraulically pumped material, only dewatered and transported material could be used. Transport and handling costs would make this an expensive alternative that probably will find little if any economically feasible justification. An example where this beneficial use was actually accomplished is the gully fill done by Mobile and Nashville Districts in the construction of the Tennessee-Tombigbee Waterway.

b. Topography Relief. Another means of using large quantities of dredged material is building hills for landscape diversity on large, level recreational sites. While this also usually would apply only to dewatered material and would also be costly, it has been considered in planning by the Fort Worth District in the special case of new work dredging in the Trinity River due to the huge quantities of material to be moved. It is being practiced in modification in the Red River Navigation Project in Louisiana, where new cut work is being used to build up island sites in the river to a level higher than the floodplain for recreation. These Red River sites employ hydraulically deposited material.

c. Earthen or Earth-filled Dams. In areas where reservoirs for flood control, recreation, or other purposes are planned, dewatered dredged material could be transported and used for construction of either earthen or earth-filled dams. This alternative would only be feasible in locales where other sources of borrow material are more costly or unavailable.

d. Institutional Use.

(1) Institutional use includes all public service/municipal uses of dredged material containment areas such as electric utilities, transportation systems, and water and wastewater facilities.

(2) One case study is Pleasure Island, bordering the Intracoastal Waterway near Port Arthur, Texas, a 3,500-acre land area formed from over 50 years of silt and sand disposal. A rock dike protects a small portion of the island that is presently developed. Among the diverse facilities developed thereon are a university campus (Lamar University), an Army Reserve Training Center, and a CE Area Office. Two recently constructed rock dikes will encourage further institutional facilities including an already planned sewage treatment plant.

(3) Another example is in Salem County, New Jersey, where a 1967 land exchange negotiated between the CE and the local public utility company has resulted in the construction of a nuclear power plant on a 200-acre disposal site. The first of four units commenced operation in 1976; the remaining units were on-line by 1979 and 1980. The site was originally a sandbar upon which fine-grained material from Delaware River dredging over the past

70 years had been placed to form a peninsula; it is now called Artificial Island.

CHAPTER 15

CONSTRUCTION AND INDUSTRIAL/COMMERCIAL USE

15-1. Harbor and Port Facilities.

a. The economic potential and social productivity of industrial/commercial activities provide a strong incentive for urban growth and development. These activities have flourished in natural harbors and along urban waterways where raw materials can be received and finished products shipped most economically. Industrial/commercial development near waterways has been aided by the availability of hydraulic fill material from nearby dredging activities. The use of dredged material to expand or enhance port-related facilities has generally received local support because of the readily apparent potential benefits to the local economy. Approval of the disposal operation is generally predicated on the advancement of the port development project and not on the incidental need for proper disposal of the dredged sediments. Traditionally, where disposal has been to advance the industrial development goal, attempts were made to use the dredged material beneficially; where it would not, the material was disposed of by the most economical means available. The key for the beneficial use planner is to identify how, when, and where dredged material from a navigation project can fulfill an economic need, while not overlooking biological beneficial uses and environmental considerations and limitations. Identification of economic or social benefits may help overcome some environmental opposition to disposal sites. Job-producing planned uses in cities with depressed employment are much more likely to gain approval than projects that appear to conflict with basic community needs.

b. There are numerous examples of dredged material sites that were used in harbor/port development. One such facility constructed on dredged material is the Presidents Island-Memphis Harbor Project located approximately 5 miles southwest of Memphis, Tennessee (Figure 15-1). It is a 960-acre site on the southeast side of the island (now a peninsula) filled with sandy dredged material. A slack-water area was created by diking, and an 800-foot-wide by 12-foot-deep channel was dredged and the sediments placed along 3.5 miles of the channel’s north bank. Filling was completed in 1957, and within 20 years most industrial development was completed. By 1973 over 70 separate industrial concerns had bought or leased acreage on the site. A feasibility study of proposed harbor expansion alternatives prepared by the Memphis District recommended that a second harbor channel be dredged at Presidents Island and the material placed on the island along the new channel’s south bank. This proposal would create an additional 1,000 acres above the floodplain for port and related industrial/commercial facilities. When the first facility was completed, there was little concern for the wetlands that were covered up. Expansion plans must take these wetlands into careful consideration.

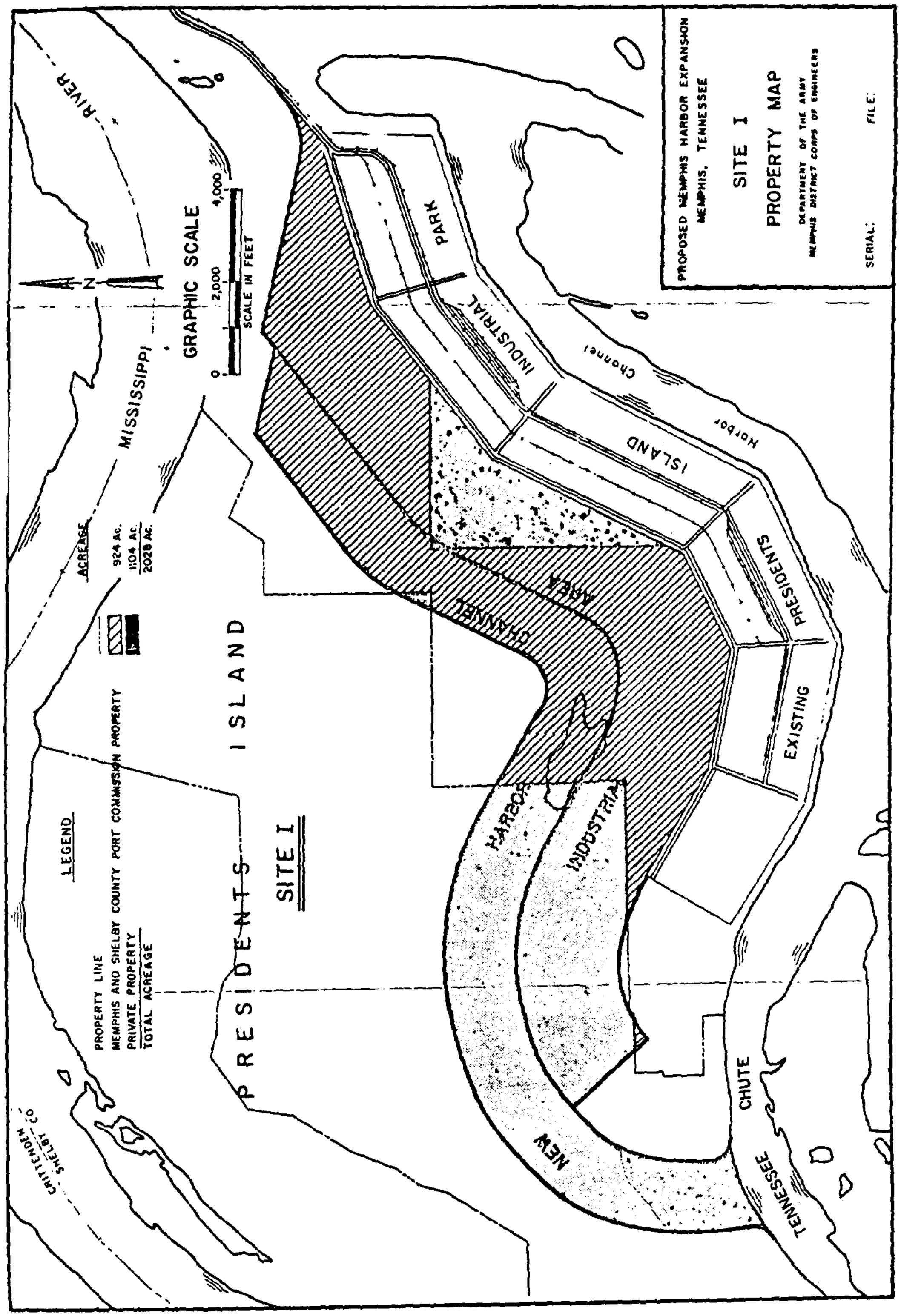


Figure 15-1. Presidents Island-Memphis Harbor Project

c. In dozens of locations in U.S. rivers, dredged material is used for such benefits and for creating foundation above the floodplain for grain elevators, shipping terminals of all types, barge-fleeting areas, and storage facilities for U.S. products waiting to be moved to market (coal, timber, agricultural products). Two examples at Portland, Oregon, a container facility and a grain elevator located at convenient shipping points, were both built on dredged material (Figure 15-2). Another example is the harbor at Vicksburg, Mississippi, on the lower Mississippi. A large industrial site providing facilities to over 50 industries was built on dredged material from the Yazoo River (Figure 15-3). Other examples include port and shipping facilities at Texas City, Galveston, and Houston, Texas, in Galveston Bay; port facilities in the Duwamish River in Seattle, Washington; and facilities at Blakely and Brookley Island complexes in upper Mobile Bay, Alabama.

15-2. Residential and Urban Use. In spite of the sometimes poor foundation qualities, dredged material containment areas have become sites of multiple-building high- and low-rise residential and business complexes. Success has been attained where the properties of the dredged material have been properly accounted for in the residential design. A few examples of residences and businesses built on dredged material include:

a. Almost the entire City of Galveston, Texas, where dredged material has been used for fill, erosion control, hurricane protection, foundation material, and other beneficial uses for at least the past 70 years.

b. Thousands of residences and businesses have been built on sandy dredged material in Tampa, St. Petersburg, Clearwater, Sarasota, Miami, Jacksonville, and numerous other locations in Florida. (Most of these were built in wetlands, and therefore much of this type of development in Florida has decreased significantly in the past 10 years.)

c. Residential areas in the Burrough of Bronx in New York City.

d. Residential and business areas throughout the City of New Orleans, both on the riverfront and on Lake Ponchartrain.

e. A combined use of sandy dredged material over the past 60 years on the Mississippi Gulf Coast for residences and businesses, highway fill, sea wall protection, and beach nourishment (for both recreation and nesting habitat for the least tern).

f. Businesses at Jackson, Mississippi, where borrow material was dredged from inside the Pearl River levee and pumped into place outside the levee for foundation material.

g. A huge industrial/residential/commercial complex, including a marine park, was built on sandy dredged material at San Diego, California (Figure 15-4).

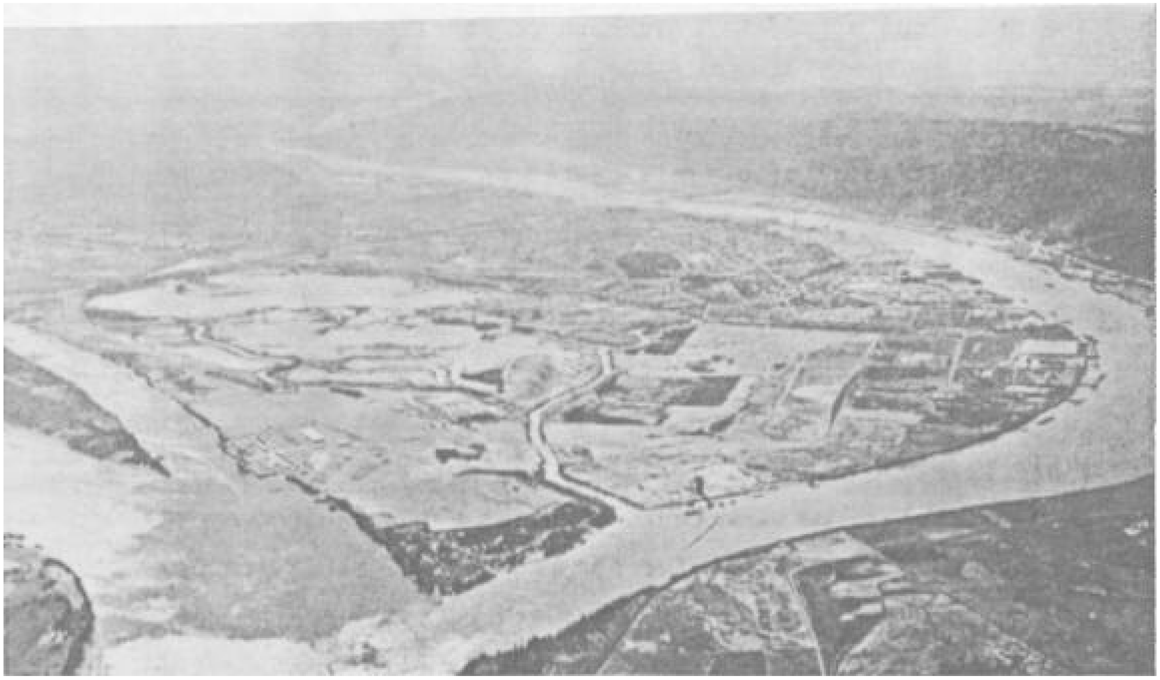


Figure 15-2. Two port facilities built on dredged material at Portland, Oregon, at the confluence of the Columbia and Willamette Rivers. A container port is located on the Columbia (left) and a grain terminal is located on the Willamette (right)

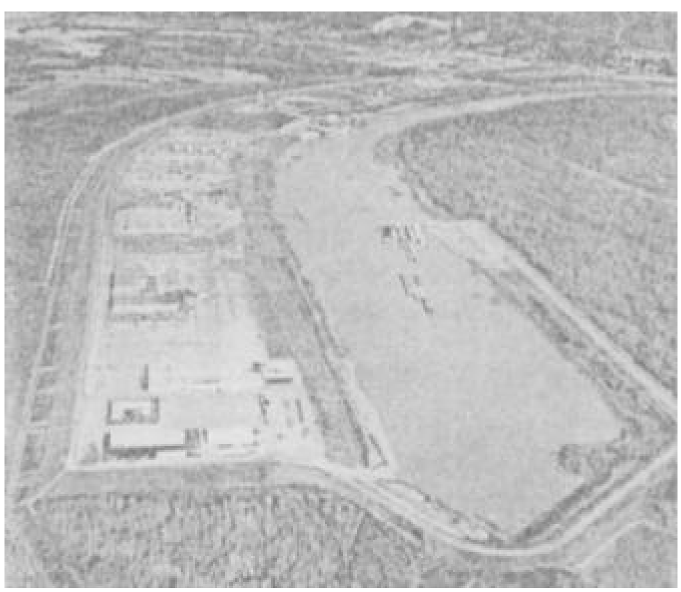


Figure 15-3. The port and industrial park at Vicksburg, Mississippi, which were built from dredged material from the Yazoo River

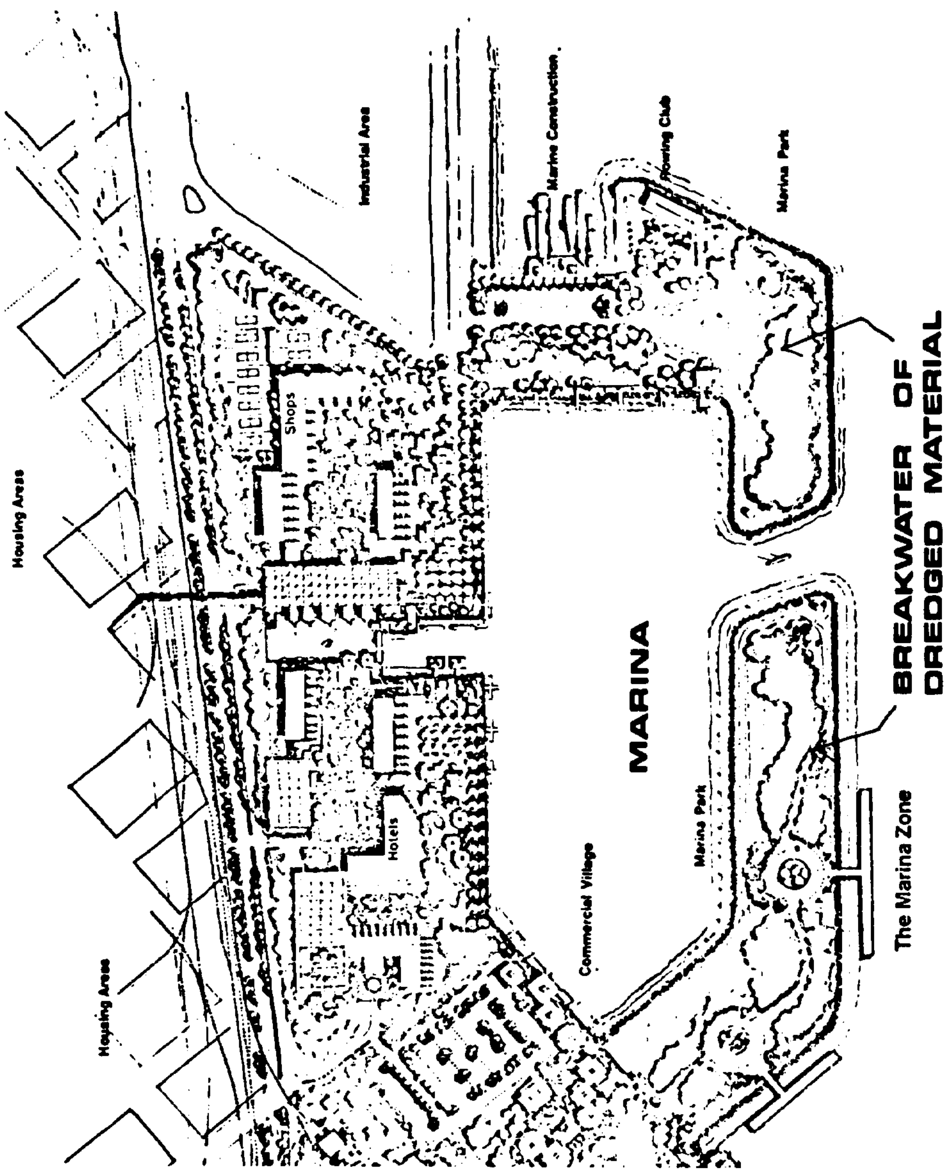


Figure 15-4. The master plan used for construction on sandy dredged material of an industrial/residential/commercial complex, including a marine park, at San Diego, California

h. A large, shopping center complex was built on dredged material at Swan Island on the Columbia River in Portland, Oregon. It included shopping and commercial areas and low-rise office buildings (Figure 15-5).

15-3. Airports. Airport runways and facilities in New York City, New York; Washington, D.C.; Grays Harbor, Washington; Minneapolis, Minnesota; New Orleans, Louisiana; Portland, Oregon; San Francisco, California; Brookley Air Force Base; and a number of other coastal areas have been built on dredged material foundations. These were built in areas where insufficient land was available for a commercial airport, and use of dredged material was easily justified both economically and socially. Such uses of dredged material will undoubtedly continue as harbors and cities increase in congestion and population.

15-4. Dikes, Levees, and Containment Facilities. The CE makes almost constant use of dredged material for dikes, levees, and confined disposal facilities (CDFs). Dredged material, pumped onsite and dewatered, readily lends itself to these uses. By using dredged material to build or increase capacity in CDFs, or for dikes and levees, overall project costs can be reduced while not having to use fastland soil for these projects and by expanding the life of existing containment sites. Some local and state agency and private use is made of dredged material for dikes and levees in certain situations such as for erosion and flood protection, or for private industrial dredged material containment facilities.

15-5. Fill Material and Roads. Thousands of cubic yards of dredged material have been dewatered in holding areas, then given or sold to public or private interests for fill material. This material has been used for a variety of building and parking lot foundation and site capping uses, primarily in urban areas. It has also been used for road construction as foundation material, especially in coastal counties. Often, such material is given away without charge in order to make room in disposal sites for subsequent disposal. In St. Paul District, dewatered sandy material was used to fill in an abandoned gravel quarry that was a dangerous eyesore. These beneficial uses, coupled with minimal handling requirements, make these disposal alternatives inexpensive and attractive.

15-6. Islands and Historic Preservation. On the Mississippi, Louisiana, Alabama, and Florida coasts, historic sites on barrier islands and beaches have been protected from wave erosion and subsidence by sandy dredged material being pumped around and near such sites. Excellent examples are found in Mississippi where the beach front, with its historic colonial and antebellum landmarks, and Ship Island, where historic Fort Massachusetts is located, were restored with sandy dredged material after both were almost totally demolished by Hurricane Camille.

Figure 15-5. A large shopping mall, Port Center, was built on dredged material at Swan Island on the Columbia River at Portland, Oregon. It included shopping and commercial areas, as well as low-rise office buildings.

15-7. Considerations.

a. The use of dredged material as industrial/commercial and construction material requires almost no additional work on the part of project engineers, unless it involves a CE work project, once material has been placed inside a containment facility and dewatered. Users and sponsors of the dredged material site at that point are responsible for moving and handling the material, developing the site, management and maintenance, and all other aspects of industrial/commercial site use. If the dewatered material is to be used for dike and levee construction, normal earth-moving and handling procedures by the CE would apply, and generally would not involve use of a dredge. Techniques outlined in items 17, 30, 62, and 82 are referenced for dike and CDF engineering design and construction. Industrial/commercial use of dredged material is probably one of the most inexpensive beneficial uses. Its primary advantage other than low cost is that it allows greater use of disposal sites when dredged material is removed. Its primary disadvantage is that on sites that become industrial areas, port facilities, airports, and other such commercial ventures, the sites are no longer available for disposal, and other disposal sites must be located and obtained.

b. While there are a number of obvious economic advantages to these types of beneficial uses, the environmental aspects may be so disadvantageous that a project is not feasible. For example, most of these sites already built displaced wetlands and other critical habitats. This can no longer be done without mitigation and stringent permit requirements.

CHAPTER 16

BASELINE AND MONITORING STUDIES

16-1. General.

a. Potential beneficial uses of dredged material should be thoroughly examined as part of preproject planning studies. Preliminary surveys of existing and candidate sites should be made during the reconnaissance phase of new studies, and detailed aerial and ground surveillance should be conducted for feasibility studies. Results should be displayed in the appropriate format in feasibility reports, including pre-authorization survey reports. Project environmental assessments and environmental impact statements must include a detailed comparison of alternative sites, including adverse and beneficial impacts.

b. Modern tools such as remote sensing, visual data management systems, and automatic data processing should be employed to help determine the most appropriate locations and best uses for dredged material. High resolution aircraft-collected scanner imagery and color infrared photography can provide detailed land-use information that can be directly analyzed by computer. Information obtained through remote sensing not only provides a valuable database, but can be used to monitor changes in existing conditions with or without the project. A variety of computer systems and software programs are available for analyzing data.

c. Coordination with other Federal and state agencies is essential for projects that include dredging activities. Scoping meetings should be held at regular intervals throughout all phases of project planning. Agencies and organizations that should be involved in scoping activities include the EPA, FWS, NMFS (when operating in coastal waters), state coastal zone management agencies, state fish and wildlife agencies, and state and Federal cultural resource agencies. Other state and local organizations, both public and private, should be included as appropriate. Adequate review time must be provided for agencies to comment on proposed actions.

16-2. Monitoring.

a. Background. This section describes the needs, considerations, and some methods for monitoring dredged material operations prior to, during, and after dredging in order to have a clear picture of the dredging and beneficial use impacts and values, as well as a source of pertinent references on monitoring. Monitoring within this section focuses only on those beneficial uses of dredged material that are derived from vegetation and/or animals.

b. Need for Monitoring. Monitoring of a proposed or existing dredged material site for the purpose of planning appropriate beneficial uses is an absolute necessity to ensure compatibility between or among the proposed uses and the dredged material disposal activities. Monitoring is important for numerous reasons. It provides a framework or database from which logical beneficial use alternatives can be proposed. For example, if waterfowl habitat is desired for hunting use, but monitoring data indicate that marsh cannot be established because of too much wave energy, it makes little sense to consider duck hunting as a beneficial use. Monitoring also documents that appropriate planning of dredged material uses has been implemented and provides a basis from which defensible arguments can be made for selected beneficial uses. Monitoring is useful in obtaining an understanding of potential problems with alternative uses of dredged material, constraints, or possibilities related to dredged material management. It provides a clear picture over time whether the planned beneficial uses develop properly or at all and what changes are taking place that influence those uses or other potential beneficial uses. For example, Miller Sands Island planted as an upland goose resting/grazing pasture in the Columbia River has reverted to use primarily by nutria because the sandy pasture has not been maintained by soil amendments and by trapping of the nutria. The nutria eat the good grasses and herbs planted for goose pasture and leave only horsetail, an unpalatable plant. A monitoring program can indicate if these kinds of situations are developing so that remedial actions can be taken that will preserve the intended beneficial use.

c. Considerations of Monitoring. In planning and initiating a monitoring program of beneficial uses on dredged material, one must consider a variety of factors that are likely to impinge upon both dredging operations and the intended beneficial uses. These impingements may take place prior to, during, and after dredging and can influence decisions as to what beneficial uses should be planned and how they are likely to change over time. The level of attention needed will be greatest in the initial stages (i.e., monitoring the disposal process, overseeing propagule collection and planting, etc.), and will in most cases decrease with time (item 32). Influencing factors that should be monitored include such things as soil or substrate conditions; size and location of site; plants and animals presently on the site or in nearby areas; natural succession typical of the area; existing and future site use; flooding and/or wave energy conditions; tidal conditions; social and economic considerations; and the probability of future dredged material deposition. This section suggests a general monitoring approach to follow after the decision has been made to develop selected beneficial uses on a site. It assumes that legal restrictions, site availability, site capacity, and other legal, administrative, or engineering aspects are favorable.

d. Methods. Beneficial use monitoring may be planned for two kinds of sites: an established dredged material site where deposition has been completed, and a site where proposed or ongoing deposition of dredged material is taking place. In the first case, an established dredged material site may be many years old or relatively new, and may be vegetated or unvegetated. In the second case, the new substrate at any one or more topographic elevations will dictate whether the site will be aquatic or upland or a combination of the two. The approach should be tailored to the kind of deposition. Monitoring of a site involves numerous factors and therefore can be most effectively accomplished by a multidisciplinary team, generally including a wildlife biologist, botanist, soil scientist, engineer, fisheries biologist, land use planner and, in some cases, a lawyer. The team needs to be structured according to the anticipated uses of the site. For example, it makes little sense to include a fisheries biologist if an upland site without any ponds or lakes is the site being considered for beneficial uses unless ponds or lakes are anticipated. Four steps for each item to be monitored should be followed: develop a statement of objectives, identify the population or unit to be sampled and data to be collected, specify the precision of data collection, and select an efficient sampling design.

(1) Physical factors. Physical factors considered important to monitor include such things as: climate; geographic location and size; topography and configuration; physical and chemical characteristics of the substrate to be deposited upon and material to be deposited; tides, currents, and other hydrological data; physical and chemical characteristics of the water in which material is deposited; and land use.

(a) Climate. Climatic data are important to monitor because they will dictate what kinds of plants and animals can ultimately grow and reproduce at the site. In a dredged material disposal project it is usually impractical to personally collect climatic data over a long enough time period to be meaningful. Therefore, resort to the literature and data sources that apply to the site area. First evaluate climate on a large scale because climate changes are relatively slow. Changes in such things as soils and vegetation will usually occur gradually. Soil and plant communities are relatively stable and mutually compatible over extensive land areas. Classification of climates over large areas requires development of parameters such as temperature and rainfall extremes on a macroscale. Maps available from the U.S. Department of Commerce enable determination of approximate limits of average minimum temperatures, rainfall distribution zones, major climatic zones, and other zones that influence types of vegetation that can be grown in an area. Determine climatic conditions on a microclimatic scale, or those climates within the first few feet of the soil. It is important to characterize these because they determine more accurately whether plants and animals will be able to survive drought, chilling, or frosts, or excess moisture. Those microclimates characterized by low precipitation during the growing season will have a deficit of moisture for plant growth, especially if temperatures are high. For example, St. Paul, Minnesota is in a semi-humid grassland-forest transition zone because it has a mean annual precipitation of 25 inches. However, San Antonio, Texas, with the same mean annual precipitation has semi-arid vegetation because of higher temperatures (70°F vs. 44°F). Soil-water losses are greater in Texas than Minnesota. To obtain these temperature and rainfall data at a local level, the planner should refer to local meteorological data furnished by the nearest National Weather Service station or establish an onsite weather station obtainable from scientific instrument supply distributors. If the latter option is selected, data should be collected in the area for as long as considered practical, preferably for at least 2 to 3 years.

(b) Geographic location and size. Geographic location will determine an area’s macroclimate and microclimatic characteristics, which will in turn influence plants and animals. The potential or existing size of a disposal area should be considered in relation to its location; these interrelated factors determine an areaÆs potential value for various beneficial uses. This is particularly true for the development of wildlife habitat. Small areas may offer no appreciable habitat development potential, whereas large areas may offer numerous management possibilities. Location of the site is extremely important, perhaps much more so than the size. Item 13 relates an example that illustrates this. A 2-acre upland site surrounded by marsh and located very close to the mainland may support a greater diversity of wildlife species than a 10-acre island site with similar habitat but isolated by open water from marsh and mainland populations. The smaller site may often be used by marsh inhabitants such as rails, herons, egrets, and raccoons; it may be visited by white-tailed deer and many small land birds; and it may support a high marsh rabbit population due mainly to the abundance of surrounding marsh vegetation. Natural plant succession and dispersal of animal species occur quickly and easily due to the area’s proximity to plant and animal sources. The island site, although larger, may be used only by waterbird species. Natural succession. and animal dispersal to the island are slower due to the island’s isolation. Often dredged material islands are the only areas available for bird colonies, and the isolation keeps predators and human disturbance to a minimum.

(c) Topography, configuration, and land features. A siteÆs topography and configuration must be examined because these factors greatly influence potential beneficial uses. The elevation of the dredged material in relation to mean water level will determine, for example, the kinds of vegetation and habitat that can be developed. Figure 4-1 in Chapter 4 illustrates this point. Configuration of the site plays a large role in determining what uses should be planned. Coves on a dredged material island, for example, can lead to successful marsh establishment (item 2) because protection from long wind fetches is provided. Topography and land configuration also relate to an area’s erodibility, flooding potential, waterway traffic, and future deposition plans. Hills, bluffs, and man-made features will influence accessibility and ease of developing desired beneficial uses. Monitoring of these factors is best achieved with an aerial photograph, topographic map, and diagram as a base. Elevational and bathymetric data may be unavailable and will have to be established by standard survey and geodetic procedures. A map or diagram should show access routes, both land and water, as means of transporting equipment; these routes should be rated. The map or diagram should show dikes, mounds, or other evidence of previous disposal. Note areas of debris accumulation and indications of nearby human activity such as a boat dock, cabin, foot trail, or livestock. See references in item 19 for techniques on reconnaissance mapping.

(d) Soils or dredged material substrate. Analysis of core samples and soil sampling data should be made on existing soils to determine undesirable physical and/or chemical properties that may pose a hazard to potential site use. If proper procedures are not taken, it is possible that buried undesirable materials could migrate upward through the water column. See item 47 for procedures to be used in sampling and analyzing soils, and for ways to handle any potentially hazardous soils. If the dredged material sediments already in place are to be used for beneficial uses, some physical and chemical tests must be conducted. Soil properties influence kinds of plant species that can be grown on the site or that will invade the site. These plants, in turn, will ultimately affect other beneficial uses to be planned. Similar physical and chemical soil tests will also be necessary for dredged material sediments, since these materials will be the growing medium for plants. See item 47 for the determination of soil or sediment properties. After soil properties are determined, soil scientists should be consulted to determine which soil treatments are required to ensure adequate plant development. Periodic monitoring of the siteÆs soil properties should be carried out since fertilization and other soil amendments and physical treatments may be necessary to ensure site beneficial uses are not adversely affected by changing soil conditions. The frequency of monitoring will largely be determined by economic and time constraints.

(e) Tides, waves, currents, and other hydrologic data. These factors influence water and nutrient availability to plants and animals and cause erosion. For salt marsh development, vertical elevation of a substrate with respect to tidal fluctuations determines the number of times per year the substrate and plants will be flooded with saltwater. The average number of hours submerged per month and the average number of hours submerged during daylight are important in determining plant distribution (item 10). Because of the energy and potential erosion they exert upon a site, waves can influence plant establishment. Fetch, or the distance wind travels across water to reach land, and the depth of water are primary determinants of the degree of wave energies. Item 37 relates a method for evaluating wave climate based on observed relationships between fetch, shore configuration, grain size, and success in controlling erosion in 86 salt marsh plantings in 12 coastal states. Of course, direct measurements for characterizing tides and waves can be accomplished through electronic gauges or by physically reading tides and waves on staff rods. Currents are normally considered when dredged material is deposited in rivers and streams. Currents have a direct effect on whether plants can become established. Current meters should be installed on the site and monitored for several months throughout the year to obtain a knowledge of maximum and minimum current conditions. Other hydrologic factors such as water table and water levels or depths will directly influence planned beneficial uses due to their effect on plant establishment and zonation. Water table, levels, and depths will influence the ability of plants to carry out their physiological processes (e.g. photosynthesis, respiration). Some plants can tolerate more or less water than others, which will in turn dictate what vegetation can be grown on a dredged material site. The vegetation will largely dictate the kinds of animal habitat that can be developed or the kinds of animals that will use the site. A procedural guide for monitoring such things as depths to water table and other hydrologic factors can be found in Item 47.

(f) Water quality. Salinity, pH, turbidity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), and mineral nutrients within the water column will largely influence the kinds of plants and aquatic fauna that will develop on or adjacent to a dredged material site. They should be monitored periodically prior to, during, and after dredging to obtain an idea of how water quality conditions might change over time, which in turn might affect plant and animal development. (See Section 2-4 of this manual for sampling and laboratory requirements and procedures regarding water quality factors.)

(2) Biological factors. Biological factors considered important to monitor include such things as: aquatic, semiaquatic, and upland plant species; all animals species including soil macroinvertebrates, microfauna, and benthos; and shellfish and finfish.

(a) Vegetation. Knowledge of existing plant species on or adjacent to the site will enable plant species selection. Indigenous plants may be desirable for various beneficial uses such as wildlife habitat development, agricultural, forestry, or horticultural purposes. Map the vegetation composition and distribution, either from visual estimation or sampling. Reconnaissance mapping and map use for various purposes, including wildlife and vegetation, and a guide to gaining natural resource information through remote sensing techniques are discussed in item 19. This guide includes vegetation and animal habitat inventory and assessment. Item 27 provides habitat analysis and evaluation methods suitable for vegetation description and other site attributes. Sampling methods are not standardized for vegetation but must be tailored to the type and areal extent of vegetation and the level of information required. Excellent general references for monitoring vegetation include items 10, 26, and 36. Item 61 provides a guide of sampling and summarizing data for plant community surveys and classification, including methods, data sheets, and computer summarization printouts. The specific location of any plants protected by law should be noted when sampling vegetation. A botanist familiar with the area should be consulted for species verification; regional botanical field guides such as items 65 and 70 will be helpful.

(b) Animals. Both aquatic and upland animals on and adjacent to the dredged material site should be monitored. Important economic species such as shrimp and other associated shellfish may be in adjacent waters and could be cultured and developed on the dredged material site. Furbearing animals such as beaver and otter may be in the area and could be attracted to the site for trapping pelts or other beneficial uses. Monitoring of smaller animals is important because they are part of the food web and can provide insight to use by larger predatory animals. Current and future animal use of a site, in general, should be determined through observation of signs such as tracks or browse marks, actual observations, or some form of sampling. For example, in sampling both aquatic and upland animals on dredged material in the intertidal zone of a Texas site near Galveston, monthly observations at exact locations were made. Aquatic invertebrates on the water bottom that may be covered during the dredging process or during beneficial use development should be described by species composition, abundance, and distribution. For information on sampling techniques, consult item 22, which discusses sampling of salt marsh benthos and burrows; item 50, which describes a reconnaissance technique for oysters; and item 85, which describes sampling for fiddler crabs in salt marsh. Other aquatic animal sampling and monitoring methods for plankton, periphyton, macrophyton, macroinvertebrates, and fish are amply discussed in item 83. For purposes of definition, monitoring of upland animals will include in this manual those animal species, such as waterfowl and colonial nesting birds, that use unflooded land for any of their life requisites. Item 69 provide numerous methods of monitoring primarily upland animal species. Another general reference that applies primarily to upland animal monitoring is item 34. Item 27 provides an excellent discussion on estimation of density of primarily upland animals by use of the line transect method. For dredged material that will be or has been deposited in a floodplain, item 78 provides a sampling method for floodplain arthropods although they stated there is no single sampling method applicable to studies of arthropods, as these animals vary in mobility and microhabitat preferences. Additional literature on sampling methods of upland animal populations includes items 5, 8, 35, 55, and 58. A wildlife biologist familiar with the proposed or existing dredged material site can estimate wildlife use of the site and should be consulted about the presence of threatened, rare, or endangered species. Critical habitat and areas of concern for these species must be located, protected, and/or enhanced in every dredging project.

e. Conclusion. Monitoring methodology should be tailored to the nature of the element and the overall reason for monitoring. In this case, it is to ensure that dredged material operations eventually lead to some planned beneficial uses. Monitoring methodology can be as simple as a yearly recording of presence or absence or as intensive as necessary to establish and document a management program or provide statistically reproducible data to protect legal interests.

CHAPTER 17

SITE VALUATION

17-1. Evaluation.

a. Dredging in our Nation's waterways and harbors is necessary to maintain navigation. However, the costs of dredging can sometimes be justified by documenting the benefits that can be derived from a network of navigable waterways. Tangible dollar benefits are generally savings in shipping costs realized by shippers using the waterways. In addition to dredging costs, the costs of disposal of dredged material from waterways are substantial. In conventional disposal operations potential benefits are usually ignored, and the cost of the disposal operation is simply part of the total cost of the entire dredging-disposal project.

b. Dredged material can provide socioeconomic benefits if beneficial uses are implemented. Uses of either the material itself or the containment area in which it is placed are options. Land enhancement benefits from the placement of dredged material can be substantial, and highly productive habitat can be developed on disposal sites. The value of new or filled land or a wetland or other habitat created by disposal of material dredged from a project is a valid benefit that can be credited to the overall project. Both new and maintenance dredging projects should evaluate land enhancement and beneficial use alternatives. An analysis should also be made of the associated socioeconomic benefits and costs of the disposal of dredged material. This process should consider several alternatives for disposal including beneficial uses, and should consider all benefits and costs, tangible as well as intangible. A number of factors need to be considered in benefits, including attitudes and opinions of local citizens, resource agencies, and environmental groups, the general public good, and distinguishing or limiting historical or archaeological features.

c. To aid in the evaluation of the land enhancement value and associated benefits that can be derived by the beneficial use of dredged material containment areas, a land value methodology has been developed for certain types of beneficial uses. The methodology is basically designed to provide guidance for projects still in the early planning stages and produces estimates of the direct market value of the created land, the related community benefits, and adverse impacts from the land use. The use of this methodology can help highlight the many advantages of the beneficial land use of dredged material. Project sponsors and local officials may gain wider public support for beneficial use projects if they can effectively demonstrate to the community the full range of benefits from project implementation.

17-2. Methodology.

a. Basis of Appraisal. The basis for the land value portion of the methodology is the comparable sales approach often used in real estate appraisal. This approach was considered the most appropriate for the value estimate of newly created land from dredged material. For the assessment of associated benefits and adverse impacts resulting from the land-use project, a matrix has been devised to categorize and describe all relevant effects. The methodology itself can be divided into: site description, establishment of use potential, estimate of value, and associated benefits and adverse impacts. The first three collectively estimate the site value changes; the fourth identifies the associated benefits and/or adverse impacts of the land-use project.

b. Site Description. Before an analysis of the value of a site can begin, the site must be described in terms of its physical features, environmental setting (including natural and man-made areas), and relationship to the economic structure of the area. This phase of the methodology is primarily a data base for subsequent analyses. Many of the items of importance to the value of the prepared site will emerge during the course of this data-gathering task. Taking the required time to develop the data needed for this section of the methodology, the final estimate of value can be made with more confidence.

c. Establishment of Use Potential. This section of the methodology establishes the most likely and the highest and best use of the containment area after the dredged material has been placed, dewatered, and consolidated. Normally, the highest and best potential use of a piece of land, within existing legal and institutional constraints, is used as the basis for the value assessment. Values of comparable land in the area determine the value of the new piece of land. The use potential is established by identifying current land uses surrounding the site, the need for certain land uses within the area, the zoning intensity of various levels of development, and other institutional and legal constraints. Also, the physical characteristics previously identified must be considered. For example, a disposal site made of fine-grained dredged material will not be suitable for high-rise developments despite other positive attributes, but it may have use as a recreation site where low-load structures may be safely erected, or as a wildlife habitat and nature area. Finally, the accessibility of the site to the existing infrastructure is an important determinant of practical use potential.

d. Estimate of Value.

(1) This is the final stage of the methodology in the actual site valuation process. For the successful accomplishment of a value estimate, an economist or real estate appraiser familiar with land values should be involved. Three key functions must be performed in the estimation process:

(a) Land parcels similar to the site to be created by the containment area and for which there are recent sale or assessment data must be identified.

(b) An estimate of demand or need for the new site must be made based on the information obtained in the estimate of use potential.

(c) The relative applicability of the comparable sites versus the new site for beneficial uses must be determined.

(2) Values of comparable parcels are the basis on which the market value estimate is made. Once the comparables have been identified and their value established, a utility estimate is made to determine how similar, with respect to “value-producing” factors, the comparables and the new site are. If the comparables and the new site are similar with respect to accessibility, zoning restrictions, proximity to public services, foundation constraints, etc., then the comparables can be considered to have equal utility to the new site and be used to establish site value. Using the relative utility measure and the demand for the new land use, an adjusted value for the new site can be estimated. By comparing this value estimate with the original value of the site before the dredged material was deposited, a land enhancement benefit can be estimated for whatever beneficial use that has been proposed.

(3) Before an estimated land valuation can be determined for other than upland human-use sites, values must be determined for such potential site uses as wetlands and other types of habitat development, nonconsumptive recreation, fish nursery areas, commercial and noncommercial shellfish and finfish industries, aquatic vegetation, endangered species critical habitat, water quality, and other difficult-to-estimate variables. These types of values are extremely controversial and hard to assess. None of the scientists working in their fields in the development of values agree on uniform estimates. Values often need to be assigned on a site-specific basis. WES has been coming to grips with this problem through the Dredging Operations Technical Support Program and Wetlands Research Program. WES often assists Districts in reaching estimated values of new or proposed dredged material or mitigated sites.

e. Associated Benefits and Adverse Impacts.

(1) The direct increase in market value of a site from the placement of dredged material is an important land enhancement benefit; however, the induced associated benefits and/or adverse impacts can also be substantial. These benefits and impacts may touch many different economic groups in a wide geographic range away from the site. The methodology can assist in identifying these benefits and impacts, describing their magnitude and significance, and displaying them for decisionmakers and the public.

(2) Two guides were developed by Conrad and Pack (item 15) to assist in identifying the significant benefits and impacts resulting from the beneficial use of dredged material containment areas. One guide graphically shows the relationships of various categories of effects which could result from a productive land use. The other lists specific types of social, economic, and environmental factors that might be affected by the beneficial use. These

guides are by no means all-encompassing but provide a framework for identification of the important benefits and adverse impacts.

(3) Once the benefits and adverse impacts are identified, a matrix can be used to describe and evaluate them. The matrix should have a simple structure, and the evaluation is based on the judgment involved in the process. No general weighting system was considered appropriate for the evaluation of these associated benefits and adverse impacts. However, a matrix should allow this subjective evaluation to be displayed so that other interested parties can review them. An important point should be remembered when using this methodology. The entire methodology is intended as a set of guidelines, and it involves the application of sound judgment in a multidisciplinary group. Deviation from the methodology may be warranted where sound judgment dictates that the situation being investigated does not lend itself to application of the methodology, such as when dealing with habitat applications of a site.

17-3. Case Studies. In developing the methodology, 15 case study sites were examined and the methodology tested on each (item 15). As developed, the methodology is to be used on undeveloped sites for planning purposes. Sites that were already developed were selected in the interest of getting a diverse group for testing. The results of the case studies indicated that the methodology is flexible and adaptable to a wide range of sites. Table 17-1 lists the case study sites along with their physical and dredged material characteristics. Table 17-2 shows the settings of the case study sites. Table 17-3 is a compilation of the estimated change in land values of the sites as a result of developing them for upland beneficial use. The values indicate that, through beneficial use application, dredged material containment areas can realize significant increases in value. The wide range of value increases shows that the value increase is a site-specific characteristic. The methodology, however, allows an estimation of this change before the site is developed. Table 17-4 is presented to show the types of associated benefits and adverse impacts that were encountered during the case studies. Details of the case studies are available in item 15.

17-4. Use of the Methodology. The large land enhancement benefits that can accrue from the beneficial use of dredged material make this alternative to conventional disposal particularly attractive. The methodology described in Chapter 17 is a tool that can be used in the planning stages to identify and evaluate both the tangible increase in market value and other benefits to be derived from beneficial upland land use. Use of this methodology can only serve to point out these benefits and/or adverse impacts so that appropriate disposal alternatives will not be overlooked. The methodology does not apply to sites not used as upland human-use sites such as wetlands. See para 17-2d(3) for a discussion of other site valuation.

Table 17-1

Case Study Site Physical and Dredged Material Characteristics (item 15)

Site	Location	Approximate Size: ha	Approximate Size: acres	Soil Characteristics: Type	Soil Characteristics: Grain Size	Soil Characteristics: Bearing Capacity	Soil Characteristics: Vegetative Support	Depth to Foundation Strata: m	Depth to Foundation Strata: ft
Anacortes	Anacortes, WA	11	26	Sand/ clay	Fine	Fair	Good	8	25
Artificial Island	Salem County, NJ	81	200	Silty clay loam	Fine	Fair	Good	21	70
Bay Port	Green Bay, WI	233	575	Sand/ clay	Fine	Poor	Good	5	15
E. Potomac Park	Washington, D.C.	133	329	Silt/ clay	Fine	Poor	Good	31	100
Fifth Avenue Marina	San Diego, CA	9	22	Fine sand	Fine	Fair	Good	NA	
Florida State Fairgrounds	Hillsborough Co., FL	112	276	Silt/ clay	Fine	Poor	Good	NA	
Hookers Point	Tampa, FL	162	400	Silt/ clay	Fine/ medium	Fair	Good	NA	
Hoquiam	Hoquiam, WA	18	45	Sand/ silt	Fine	Fair	Good	10	34
Patriots Point	Charleston, SC	182	450	Silty loam	Fine	Poor	Good	18	60
Vicksburg	Vicksburg, MS	142	350	Sand/ silt	Fine	Good	Good	12	40
Virginia Beach	Virginia Beach, VA	17	43	Sand & clay	Fine to medium	Fair	Poor	NA	
Pelican Island	Galveston, TX	1306	3225	Silt/ clay	Fine	Fair	Good	NA	
Port Jersey	Jersey City, NJ	172	430	Sand/ clay	Fine to medium	Fair	Poor	23	75
Blount Island	Jacksonville, FL	680	1700	Silt/ clay	Fine	Good	Good	25	80
Rivergate	Memphis, TN	172	425	Sand/ clay	Medium	Good	Good	NA	

Table 17-2

Case Study Site Settings (item 15)

Site Name	Productive Use	Water and Sewer	Urban Setting	Zoning	Access
Anacortes	Industrial/manufacturing	To site	Urban/port	Industrial/urban	Excellent
Artificial Island	Nuclear power plant	Home nearby; developed their own services	Rural	Industrial/urban	Poor
Bay Port	Industrial/port	Nearby	Urban	Industrial/urban	Good
E. Potomac Park	Park	Onsite	Urban	Open space	Excellent
Fifth Avenue Marina	Marine/park	Adjacent to site	Urban	Open space	Excellent
Florida State Fairgrounds	State fairgrounds	Onsite	Suburban	Urban transition	Good
Hookers Point	Industrial/port facility	Onsite	Urban/port	Industrial/urban	Excellent
Hoquiam	Industrial/manufacturing	0.2 km (0.13 mile) from site	Urban/port	Industrial/urban	Good
Patriots Point	Museum, marina, golf course, hotel	Water extended to site. Package sewage treatment plant installed.	Suburban	Commercial/ agricultural/ open space	Fair
Vicksburg	Industrial/manufacturing	Adjacent to site	Suburban	None	Good
Virginia Beach	Beachfront commercial	Adjacent to site	Urban	Residential/ commercial	Excellent
Pelican Island	Industrial/residential/ institutional/recreational	To site	Urban	Industrial/ residential/ open space	Excellent
Port Jersey	Industrial/commercial	Onsite	Urban	Industrial	Excellent
Blount Island	Industrial	To site	Suburban	Industrial	Excellent
Rivergate	Industrial	Onsite	Suburban	Manufacturing	Excellent

Table 17-3

Case Study Site Valuation Study (item 15)

Site Name	Use Considered for Valuation	Raw Value Prior to Dredged Material Placement		Adjusted Present Value		Enhancement Value	
		per ha	per acre	per ha	per acre	per ha	per acre
Anacortes	Industrial/port	$5,400/ha*	$2,200/acre	$43,200/ha	$17,500/acre	$37,800/ha	$15,300/acre
Artificial Island	Nuclear power generation	$12/ha	$5/acre	$3,200/ha	$1,300/acre	$3,200/ha	$1,300/acre
Bay Port	Heavy industrial	Nominal	Nominal	$16,100/ha	$6,500/acre	$16,100/ha	$6,500/acre
E. Potomac Park	Recreational	None		$645,900/ha	$261,500/acre	$645,900/ha	$261,500/acre
Fifth Avenue Marina	Recreational/open space	$10,800 to $26,900/ha	$4,300 to $10,900/acre	$1.94 million to $2.60 million/ha	$784,000 to $1.0 million/acre	$1.92 million to $2.60 million/ha	$779,000 to $1.0 million/acre
Florida State Fairgrounds	Commercial/retail	$11,100/ha	$4,500/acre	$106,300/ha	$43,000/acre	$95,100/ha	$38,500/acre
Hookers Point	Deepwater terminal facilities	Nominal	Nominal	$160,600/ha	$65,000/acre	$160,600/ha	$65,000/acre
Hoquiam	Industrial/port	$2,000/ha	$800/acre	$13,100/ha	$5,300/acre	$11,100/ha	$4,500/acre
Patriots Point	Commercial/recreational	$5/ha	$2/acre	$43,000/ha	$17,400/acre	$43,000/ha	$17,400/acre
Vicksburg	Industrial/port						
Virginia Beach	Commercial/retail	$5,600/front m	$1,700/front ft	$5,600/front m	$1,700/front ft	Maintenance value	Maintenance value
Pelican Island	Industrial/residential	$1,725/ha	$700/acre	$19,266/ha	$7,800/acre	$17,540/ha	$7,100/acre
Port Jersey	Industrial	$35,000/ha	$14,000/acre	$198,000/ha	$79,000/acre	$163,200/ha	$65,200/acre
Blount Island	Industrial	$16,055/ha	$6,500/acre	$83,360/ha	$33,750/acre	$67,305/ha	$27,250/acre
Rivergate	Manufacturing	$11,100/ha	$4,500/acre	$134,500/ha	$54,500/acre	$123,400/ha	$50,000/acre

* 1977 dollars.

Table 17-4

Case Study Sites--Associated Benefits/Adverse Impacts (item 15)

Associated Benefits/Adverse Impacts	Anacortes	Artificial Island	Bay Port	E. Potomac Park	Fifth Ave. Marina	Florida State Fairg.	Hookers Point	Hoquiam	Patriots Point	Vicksburg	Virginia Beach	Pelican Island	Port Jersey	Blount Island	Rivergate
Adjusted value increase						X	X				X				
Increased business activity			X		X	X	X				X		X		X
New jobs	X	X	X			X	X	X	X	X	X	X	X	X	X
Increased taxes/revenues	X		X		X			X		X	X				
Sales	X					X	X	X	X		X	X			X
Real estate	X	X	X			X	X		X			X	X	X	X
Community attractiveness				X	X	X			X		X				
General boost to economy	X		X			X	X		X			X		X	X
Operations revenue						X	X		X						
Provide needed community facilities				X	X	X	X						X		
Increased recreation opportunities				X	X	X			X		X	X			
Construction jobs		X					X					X	X		X
Utility taxes		X													X
Decrease in area taxes		X													
Public education (re: nuclear power plants)		X													
Increased congestion		X	X		X				X		X			X	
Higher property taxes												X			
Environmental degradation		X	X		X				X	X				X	
Increased municipal expenses															
Limits area development potential		X													
Community concern		X								X		X		X	
Detracts from adjacent vistas									X						
Improved medical care services		X													
Provide needed power		X													
Educational/cultural opportunities									X						
Expands area tourist potential									X						
Introduce alternative transportation mode							X		X		X		X	X	
Create site for administrative offices				X											X